Water Quality Standards Rule Packages Technical Support Document:

Waterbody assessments, biocriteria, and phosphorus resonse indicators (Rule No. WY-23-13)

V1. 6-17-2019

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1. Introduction

1.1 OVERVIEW

This Technical Support Document covers rule package WY-23-13, Waterbody Assessments, Biocriteria, and Phosphorus Response Indicators. This rule package addresses several areas related to the state's assessments of its streams, rivers, lakes and other waterbodies. It focuses largely on assessments related to the biological quality of a waterbody. The main portions of the rule package are summarized here.

Waterbody Assessments and Reporting. Every two years, under federal Clean Water Act requirements, the department assesses the state's waterbodies to determine whether they are attaining water quality standards. A new Subchapter IV is proposed that codifies Wisconsin's current procedures for conducting surface water impairment assessments, including public participation opportunities and EPA approval.

Biocriteria. The most direct and commonly-applied method of measuring the quality of a waterbody is through assessing the biological communities within the waterbody—its fish, insects, plants, and algae. A new Subchapter III establishes narrative biocriteria will provide a general outline of the types of procedures that the department undertakes to assess the quality of surface waters based on the health of their biological communities. These narrative biocriteria generally describe the types of biological assessments conducted to determine whether a waterbody's aquatic community is healthy and attaining its designated uses or is not attaining and should be placed on the impaired waters list (section 303(d) list).

Dissolved oxygen criteria for Aquatic Life. Revisions to the dissolved oxygen section are needed to clarify which criteria apply to different waterbody types:

- This rule specifies for which waterbodies and at which times the more protective dissolved oxygen criterion of 7.0 mg/L applies to protect fish early life stages that require higher oxygen levels. It specifes which other DO criteria apply to other waters and other time frames. Certain dissolved oxygen criteria are also relocated from ch. NR 104 to s. NR 102.04(4), so that all dissolved oxygen criteria are located in the same part of the code.
- This rule creates oxythermal criteria for two-story fisheries. These new criteria are necessary because the existing dissolved oxygen criteria are not appropriate for this relatively rare and sensitive type of coldwater fishery, comprising only .01% of Wisconsin's lakes.

Algae criteria for Recreation and Aquatic Life. Algae levels are a top water quality concern for the public, and are a critical component of waterbody assessments to determine whether recreational goals are met. The algae (measured as chlorophyll *a*) criteria created here are similar to benchmarks already used by the department to assess water quality for recreation and aquatic life uses. Two types of algae criteria are created: the criteria to protect aquatic life uses is based on chlorophyll *a* concentrations alone, while the criteria to protect recreation are based on the frequency of moderate algal levels, which combines a chlorophyll *a* concentration threshold with the number of days exceeding that threshold.

Phosphorus assessment procedures using biological metrics. Statewide phosphorus criteria were promulgated in 2010. However, the criteria did not include evaluation procedures for determining attainment of the phosphorus criteria in a waterbody. This rule specifies how attainment of the phosphorus criteria is determined. It also incorporates flexibility for determining impairment due to phosphorus levels by creating a "combined criteria" approach. Under this approach, the waterbody's phosphorus concentration is reviewed in conjunction with "phosphorus response indicators"—algae and plant metrics—

that specifically indicate whether the waterbody is exhibiting a biological response to phosphorus. If a waterbody exceeds the statewide phosphorus criterion (within a certain range) but does not exhibit a biological or recreational use impairment, it would not be considered impaired for purposes of section 303(d) listing.

NR 217 calculation of upstream background phosphorus concentrations. This rule includes a revision to a portion of ch. NR 217 to align the phosphorus calculation methods used to determine background phosphorus concentrations for effluent limit calculations with those delineated in proposed s. NR 102.07 (1) (a) 2. Previously, slightly different methods were used to calculate ambient phosphorus concentrations for purposes of criteria assessment and to calculate upstream background phosphorus concentrations for WPDES permit limit derivation under s. NR 217.13 (2) (d). Although these two methods yield very similar resulting phosphorus concentrations, the differences between the two methods have caused confusion and are unnecessary. The proposed procedure detailed in s. NR 102.07 (1) (a) 2, which is the method used for criteria assessment, parallels how the criteria were initially developed and will be most appropriate for both applications.

Relation of this rule to Site-Specific Criteria for Phosphorus (WT-17-12)

This rule package ties into a second rule package that is concurrently underway (WT-17-12) which creates a new chapter NR 119. The proposed ch. NR 119 establishes standard protocols for developing site-specific criteria (SSC) for phosphorus in cases where the current statewide phosphorus criteria may be over- or under-protective of a waterbody's designated uses. Development of SSC ties directly to the ability to demonstrate support of a waterbody's phosphorus response indicators and biocriteria, contained in rule package WY-23-13 and described in this document. This Technical Support Document provides a brief overview of how this rule relates to the SSC rule. The SSC rule itself does not require a Technical Support Document as it establishes a process rather than a water quality standard. Any SSC developed using that process will have its own Technical Support Document and will be evaluated for approval by EPA.

1.2 CHANGE LOG

For a quick synopsis and explanation of changes to existing codes, a "Change Log" is provided here (Figure 1). Readers may wish to refer to this resource while reviewing proposed rule revisions. It may be particularly helpful for areas of the code in which minor revisions are proposed that are not covered as part of the text of this Technical Support Document.

Figure 1. Code revisions and explanations under rule package WT-17-12, related to waterbody assessments, biocriteria, and phosphorus response indicators.

Code Reference	Revisions and Explanations
102.03 Definitions	Added definitions for the following: benthic, biocriterion, chlorophyll *a*, Clean Water Act, confidence interval, diatom, drainage lake (relocated), impounded flowing water, macrophyte, reservoir (relocated), Section 303(d) list, seepage lake (relocated), stratified two-story fishery lake (relocated), U.S. EPA.
102.04(4) Criteria for fish and aquatic life	Revised existing language on dissolved oxygen (DO) criteria as follows: (a)1 to (a)6 Specified more clearly which DO criteria apply to each waterbody type, and specify that cold DO criteria apply to all waters where coldwater species are present, rather than waters listed in the 1980 trout book. See section 5.1 in the Technical Support Document. (am) Created a new dissolved oxygen and habitat quantity criterion for two-story fisheries, since existing DO criteria are not appropriate for supporting these waters.

	See section 5.2 in the Technical Support Document for a detailed description of this section. (b) Repealed as it is incorporated into (a). (d) Split into two paragraphs, (d) for toxic substances and (g) (created) for other criteria. (f) Established chlorophyll *a* criteria for aquatic life. See section 4.2 in the Technical Support Document for a detailed description of this section. (g) (see (d) above)
102.04(5)(b) Recreational Use. Exceptions	Updated a reference to another portion of code, necessessitated by restructuring.
102.04 (6) Criteria for Recreational Use	Established a criteria for frequency of moderate algae levels for lakes, rivers, and impounded flowing waters. See section 4.1 in the Technical Support Document for a detailed description of this section.
102.06 Phosphorus	(1) Added a reference to assessment procedures in 102.07. (2) Revised definitions for greater clarity for stratified lake or reservoir and stratified two-story fishery lake. Relocated several definitions to 102.03 as they are also applicable to other parts of ch. NR 102. Added definition for weather-controlled ambient total phosphorus concentration. (3) and (4) Relocated phosphorus criteria for impounded flowing waters to sub. (3) with rivers and streams, since determination of the applicable P criterion for an impounded flowing water is dependent on whether it is located on a stream or on a river. (7) Repealed the note as it is now replaced by new 102.07.
102.07 Phosphorus assessment procedures	Established protocols for assessing against the phosophorus criteria. See section 6 of the Technical Support Document for a detailed description of this section. (1) Established general assessment procedures such as data requirements and calculation methods. (2) Established a combined approach for assessing attainment of phosphorus criteria. This approach creates phosphorus response indicators for streams, rivers, and lakes. Phosphorus response indicators are used in conjunction with phosphorus criteria to make impairment determinations. (3) to (6) Established phosphorus response indicators for various waterbody types.
Subch. III (102.40) Biocriteria.	Created Subch. III to establish biocriteria for assessment of aquatic life uses. These codify general expectations for the health of a waterbody's aquatic life community, and describe the types of assessment tools that are used for such determinations. See section 3 of the Technical Support Document for a description of this subchapter.
Subch. IV (102.50) Waterbody Assessments and Reporting	Created Subch. IV to outline the department's obligations under the Clean Water Act to conduct biennial assessments, which was not previously addressed in code. This subchapter is provided for clarity; it does not create new obligations for the department or regulated public. See section 2 of the Technical Support Document for a description of this subchapter.

1.3 RULEMAKING AUTHORITY

These rule packages will update Wisconsin's water quality standards. Water quality standards include "a designated use or uses for the waters of the United States and water quality criteria for such waters based on such uses" per 40 CFR 131.3(i). Designated uses describe the way Wisconsin intends for its waters to be used. Criteria are numeric or narrative statements of the quality of water that must be present to support designated uses. Wisconsin waters are each assigned four designated uses: Fish and Aquatic Life (now shortened to Aquatic Life), Recreation, Public Health and Welfare, and Wildlife. These rule packages assign new biologically-based criteria, biocriteria, and phosphorus response indicators to protect these uses, particularly aquatic life and recreation. Additionally, the rule package adds language that clarifies Wisconsin's obligation under the Clean Water Act (CWA) to conduct waterbody assessments using the designated uses and water quality criteria every two years and to determine which waterbodies are not meeting water quality standards.

U.S. EPA delegates the authority and responsibility for creating and updating water quality standards to the state of Wisconsin. Under Section 131, Water Quality Standards, in the Code of Federal Register (CFR):

> **40 CFR §131.4 State authority.**
> (a) States (as defined in §131.3) are responsible for reviewing, establishing, and revising water quality standards. As recognized by section 510 of the Clean Water Act, States may develop water quality standards more stringent than required by this regulation.
>
> **40 CFR § 131.11 - Criteria.**
> (a) (1) States must adopt those water quality criteria that protect the designated use. Such criteria must be based on sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use. For waters with multiple use designations, the criteria shall support the most sensitive use.

Wisconsin statutes contain the following authority for the state to promulgate water quality standards:

> **Wis. Stat. § 281.15 - Water quality standards.**
> 281.15(1) The department shall promulgate rules setting standards of water quality to be applicable to the waters of the state, recognizing that different standards may be required for different waters or portions thereof. Water quality standards shall consist of the designated uses of the waters or portions thereof and the water quality criteria for those waters based upon the designated use. Water quality standards shall protect the public interest, which include the protection of the public health and welfare and the present and prospective future use of such waters for public and private water systems, propagation of fish and aquatic life and wildlife, domestic and recreational purposes and agricultural, commercial, industrial and other legitimate uses. In all cases where the potential uses of water are in conflict, water quality standards shall be interpreted to protect the general public interest.
> (2) In adopting or revising any water quality criteria for the waters of the state or any designated portion thereof, the department shall do all of the following:
> (a) At least annually publish and provide public notice of water quality criteria to be adopted, revised or reviewed in the following year.
> (b) Consider information reasonably available to the department on the likely social, economic, energy usage and environmental costs associated with attaining the criteria and provide a description of the economic and social considerations used in the establishment of the criteria.
> (c) Establish criteria which are no more stringent than reasonably necessary to assure attainment of the designated use for the water bodies in question.

Any updates to Wisconsin's water quality standards need to be reviewed by U.S. EPA. EPA is required by Section 303(c)(3) of the CWA and 40 CFR 131.21 to review new or revised water quality standards to determine whether they are consistent with the CWA and 40 CFR Part 131.

EPA's review of water quality standards involves a determination of whether the state has adopted criteria that protect the designated use, and whether the state has followed its legal procedures for revising or adopting standards.

2. Waterbody Assessments

2.1 DOCUMENTING CLEAN WATER ACT OBLIGATIONS

Under the Clean Water Act, all states are required to conduct waterbody assessments and impaired waters listing; these are submitted to the U.S. EPA every two years. However, Wisconsin codes do not contain any reference to these obligations. The newly proposed Subchapter IV, Waterbody Assessments and Reporting, documents and codifies Wisconsin's assessment and listing process, in a generalized manner. It describes two specific types of assessments that are required under the Clean Water Act: statewide condition assessments and individual waterbody assessments (including the 303(d) list). It also establishes requirements for public participation and recognizes the U.S. EPA's approval process.

The rule addition is not meant to necessitate any specific changes to how these assessments are currently conducted. The department's protocols for assessing waterbodies and listing impaired waters are contained in a guidance document titled "*Wisconsin's Consolidated Assessment and Listing Methodology*" (WisCALM), which is updated every two years. This guidance document would still be used for more detailed protocols than those that are codified.

2.1.2 Variability and confidence intervals

This subchapter also contains a section on sample variability. For certain types of assessments, a site may exhibit a wide variability in samples collected. The subchapter establishes a process for using confidence intervals to determine when additional samples are needed to bolster the dataset before making an impairment determination.

This use of confidence intervals (CI) is a statistical approach to assess stream data against the applicable water quality criterion. Within this rule package, it is applied to both phosphorus and chlorophyll *a* assessments, and is available to use with other parameters as appropriate. Use of an 80% CI has several benefits, including:

- It clarifies the confidence in the mean or median value of a small number of samples;
- It maximizes sampling efficiency, only requiring additional samples if the results are unclear (a small percentage of the time);
- It reduces both false positives and false negatives in decision making;
- It is consistently applied for assessments across parameters (for both total phosphorus and chlorophyll *a*) and across waterbody types (for lakes, streams, and rivers); and
- It is currently in use as part of WisCALM assessment protocols and is automatically calculated.

The CI approach involves the calculation of a two-sided 80% confidence interval around the mean (for lakes) or median (for streams) of a sample dataset. The confidence interval is calculated using measures of sample size and variation to suggest, with a specified level of certainty, that the true population statistic (e.g., mean or median) falls within a specified range of values. When sample values are normally distributed, the confidence interval around the median is identical to the confidence interval around the mean. Because phosphorus and chlorophyll *a* concentrations are usually log-normally distributed, the raw concentrations for these metrics are log-transformed for the confidence interval calculation.

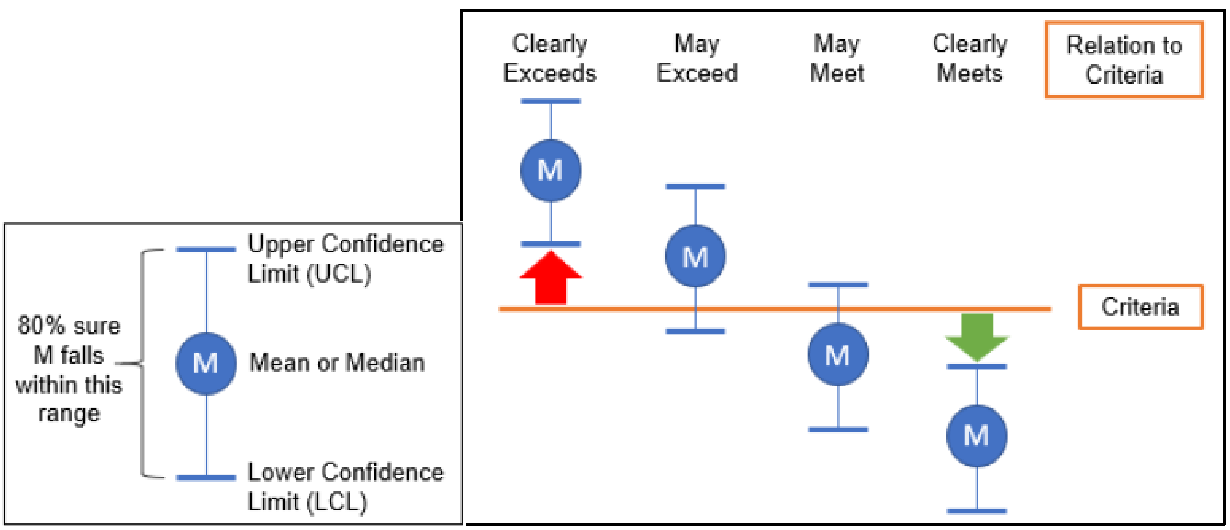
The two-sided CI has an upper and lower confidence limit (CL). The upper and lower CL are used to determine if more data are needed before making an assessment determination, as follows (Figure 2):

- If the upper CL is below the criterion, the sample dataset clearly attains the criterion. No further samples are needed.
- If the lower CL of the sample dataset from a particular site exceeds the applicable criterion, and those data were representative of normal weather and hydrology, then the corresponding site/segment is considered to be exceeding the criterion. No further samples are needed.
- If the criterion falls within the confidence interval, then more samples are needed before making an attainment determination. Typically an additional year of sampling is done to increase certainty; after that point, if results are still unclear the attainment decision is based on whether the mean or median is above or below the criterion.

By comparing only one side of the 80% CI to a criterion it provides 90% certainty that the true mean or median is above the threshold (see the "Clearly Exceeds" example in Figure 2). This is because if the 80% CI is above the criterion then the 10% uncertainty that is greater than the highest confidence limit is also above the criterion, and summing the two equals 90% confidence. Likewise, in the "Clearly Meets example in Figure 2, there is 90% certainty that the true mean or median is below the criterion.

WisCALM 2020, section 4.5, contains the formula for the CI calculation and additional information on how the CI is used.

Figure 2. Comparison of the upper and lower confidence limit values and mean/median (M) to a criterion, to determine if additional samples are needed for an assessment determination.



3. Biocriteria: Assessing Overall Health

WDNR's proposed rule revisions include a new Subchapter 3 of NR 102 Wis. Adm. Code that will establish narrative biocriteria to be used for waterbody assessments and impairment listing. This code package includes several types of biologically-based criteria, including biocriteria, which indicate the overall health of certain groups of organisms. Phosphorus response indicators are a different set of indicators discussed in section 6 that are designed to reflect impacts specifically tied to phosphorus. This section focuses on biocriteria for assessing overall health.

Wisconsin, like many state regulatory agencies, has a long history of using biological data to support water quality management (U.S. EPA 2011). The biocriteria presented here were developed using Wisconsin-specific data and statistical approaches appropriate for these datasets.

3.1 NARRATIVE VS. NUMERIC BIOCRITERIA

Most state environmental agencies assess biological quality in their waterbodies. This can be done under several frameworks: (a) guidance, (b) narrative biocriteria, and (c) numeric biocriteria. EPA has been working with states, including Wisconsin, over the last decade to develop and codify narrative or numeric biocriteria. WDNR has been assessing biological metrics, primarily fish and aquatic insects in streams and rivers, for two decades. Assessment protocols were incorporated into the department's Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) guidance starting with the 2014 assessment cycle. Because this has been longstanding practice and is an important part of WDNR's work to assess the health of the state's waterways, it is appropriate to reflect this process in state Administrative Code to provide transparency for the public and clarity as to how bioassessments fit within the Clean Water Act. Within code, biocriteria can be expressed as either narrative or numeric:

Narrative biocriteria are a set of descriptive statements in code that express expectations for the quality of aquatic biological communities, and may also provide information about the types of assessments done to assess their health. Typically, narrative biocriteria have accompanying guidance, such as WisCALM, describing assessment protocols.

Numeric biocriteria are specific numeric thresholds for each type of waterbody and each type of community (fish, insects, etc.) at which that waterbody is determined to be attaining its aquatic life use. For instance, numeric criteria may contain a table of scores for various types of fish communities within streams. For a certain stream type, the numeric criterion might say that the fish community should achieve a 40 or greater on a 100 point scale (the Fish Index of Biotic Integrity, or IBI). Other communities may have other thresholds.

At this time, the department is proposing to establish a Subchapter III containing narrative biocriteria. The primary narrative statement in the code is as follows:

NR 102.40 (2) NARRATIVE BIOCRITERIA. (a) The aquatic life uses under s. 102.04 (3), except for those specified in s. 102.04 (3) (d) to (e), shall be considered suitable for the protection and propagation of a balanced aquatic life community. Surface waters designated with these uses shall support the growth, development, reproduction, and life cycle of the aquatic life communities for their designated aquatic life use categories, although they may exhibit moderate changes in aquatic life community structure due to loss of some rare native taxa or shifts in relative abundance. A waterbody's biological quality shall be within the range of the quality found in similar waterbodies under natural conditions. A waterbody with distinct natural characteristics that result in an aquatic life community different from or less diverse than other waters in the same use category may be considered supporting its aquatic life use if those differences are clearly related to natural characteristics.

(b) A surface water that does not support a balanced aquatic life community as designated under s. 102.04 (3) (d) to (e) shall support its highest attainable use given its habitat and potential.

(c) A surface water shall maintain at least the highest biological condition it has achieved since 1975.

Note: U.S. EPA specifies November 28, 1975 as the benchmark date from which to determine "existing uses" for aquatic life (40 CFR s. 131.3(e)).

Note: Examples of waterbodies with distinct natural characteristics are wetland-dominated streams, naturally acidic bog lakes, and ephemeral streams with only small areas of short-term refugia. Biological condition assessments should not be conducted during periods when there is insufficient water due to natural conditions to support aquatic life.

This narrative statement is followed in code by a description of the types of biological assessments used by the department to assess biological condition, such as IBIs or similar tools. Primarily, these tools are housed in WisCALM, as they have previously been, though other types of assessments may be used if appropriate. WDNR is in the process of reviewing and revising the existing IBI tools for fish and aquatic insects for streams and rivers. We expect that these will be revised in time for the 2022 assessment cycle. Any proposed changes will be public noticed as part of the WisCALM guidance public notice period for that assessment cycle, which would take place in the fall of 2020. In addition to revisions to the fish and aquatic insect IBIs, we expect to include an assessment tool for aquatic plants in lakes that was developed recently based on an extensive plant dataset on Wisconsin lakes. This will be an important addition because the state currently does not have an assessment metric for the health of lake aquatic life communities. Wetland plant assessment tools may also be incorporated. This rule would not codify WisCALM, only reference its use for housing the department's typical assessment protocols. These protocols are not water quality standards in and of themselves, but provide information on how the department reviews its data.

Narrative biocriteria are, by their nature, flexible. At any given time or location, the most appropriate assessment protocols for a certain aquatic community would be applied. This means that as assessment protocols are improved over time, the newer protocols would be applied. This is similar to the existing approach where protocols are implemented through WisCALM guidance, where they may evolve over time to reflect the most recent scientific understanding of aquatic communities. WisCALM is updated every two years to incorporate any needed adjustments, and a public comment period is held at the start of each two-year cycle to get public feedback on any proposed revisions. Any revisions or additions to WisCALM would go through WisCALM's regular public comment period. WDNR has spent much of the last two decades developing bioassessment tools for all waterbody types, which are added as appropriate. Once a bioassessment tool is implemeted it rarely undergoes major revisions. For instance, the coldwater stream fish and stream macroinvertebrate biological assessment tools were developed in 1996 and 2003, respectively, and incorporated into the WisCALM protocols for waterbody assessments around 2014. During that time frame, there have not been any major revisions to the protocols.

WDNR's eventual goal is to promulgate numeric biocriteria. WDNR continues to work with EPA to make final adjustments to the IBIs and other tools. Once complete, we plan to begin a new rulemaking process to establish these numeric thresholds in code.

From EPA's website, https://www.epa.gov/wqc/information-bioassessment-and-biocriteria-programs-streams-and-wadeable-rivers-tabulated-format, EPA reports that 34 states currently have narrative biocriteria promulgated, and another five states have numeric biocriteria. Within EPA's Region 5, which Wisconsin is part of, Ohio and Minnesota have both narrative and numeric biocriteria, while the other Region 5 states do not have promulgated biocriteria.

3.2 WISCONSIN'S CURRENT BIOLOGICAL METRICS

This section provides a brief description of each type of biological metric currently in use by WDNR, as well as a recently-developed lake assessment tool. Because each of these tools are well-documented within WisCALM and the papers cited, they are not described in-depth here. WisCALM can be accessed online at https://dnr.wi.gov/topic/surfacewater/assessments.html. As mentioned above, any proposed revisions to WisCALM are public noticed at the start of each two-year assessment cycle.

3.2.1 Streams and Rivers

WDNR has a long history of assessing streams and rivers for fish and macroinvertebrates (aquatic insects). Wisconsin has made considerable investments in developing biotic indices for wadeable streams and rivers.

- **Macroinvertebrates:** Three macroinvertebrate Indices of Biotic Integrity (MIBI) are tailored to wadeable streams in specific ecoregions of Wisconsin: Driftless Area, Northern Forest, and Central/Southeast (Weigel, 2003). These subcategories are based on landscape scale characteristics including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology. In the wadeable stream Macroinvertebrate IBI (MIBI), the three macroinvertebrate IBIs tailored to each ecoregion are combined into a single Wadeable Stream MIBI scoring scale that is comparable across all ecoregions. Additionally, a separate MIBI is used for rivers (Weigel and Dimick 2011).
- **Fish:** Five fish IBIs (FIBI) have been developed for wadeable streams based on stream size (flow) and temperature, the waterbody characteristics most closely tied to fish community composition. The five IBIs are: coldwater (Lyons et al., 1996), cool water transitional (cool-cold and cool-warm; Lyons, 2012), warmwater (Lyons, 1992) and small stream (Lyons, 2006). These correspond to different Natural Community stream subcategories, which are correspondingly based on the temperature and flow of the waterbody. A separate fish IBI is used for rivers (Lyons et. Al. 2001).

Wisconsin was one of the earlier states in the nation to develop state-specific IBIs, and has had decades of experience applying these tools to our aquatic systems. Currently, because newer geographic data are available, WDNR is in the process of working with EPA to revise some of the underlying geographic data that was used to develop these tools. Additionally, these revisions may align the five fish IBI tools for streams into a more unified scoring system for ease of application and interpretation. Once the IBIs are revised accordingly, we plan to propose them for promulgation as numeric biocriteria in a separate rule package. Until such time, the existing IBI tools would continue to be applied via WisCALM under the narrative biocriteria.

Sampling protocols for fish and macroinvertebrates in streams and rivers are well established in the WDNR's Water Monitoring Strategy and standard operating protocols. No changes are proposed to the sampling protocols.

3.2.2 Lakes and Reservoirs

The department recently completed a lake plant assessment tool called the Macrophyte Assessment of Condition, or MAC (Mikulyuk et. al, 2017). This tool is ready for inclusion in WisCALM and future numeric criteria.

- **Lake plants:** Lake plants, or macrophytes, are sensitive to multiple forms of anthropogenic disturbance and can be used as a metric to signify ecological impairment (Alahuhta and Aroviita 2016, Lacoul & Freedman 2006, Wilcox 1995). The lake assessment tool is based on surveys conducted on 462 unique lakes since 2005, using a standardized point-intercept sampling method to capture data on lakewide aquatic plant community composition (Hauxwell et al. 2010, Mikulyuk et al. 2010).

  The plant assessment method clusters plant species into three groups that are sensitive, moderately sensitive and tolerant to stressors related to eutrophication, population and land use. In general, lakes in poor condition have more disturbance-tolerant plants whereas lakes in good condition have more plants that are sensitive to disturbance. Moderately tolerant plants often occur at intermediate levels of disturbance, decreasing toward either end of the disturbance gradient. This assessment method proposed by Mikulyuk et al. allows us to describe a lake's condition using aquatic macrophytes (2017).

  Macrophyte response to disturbance is subcategorized based on a North/South split, and whether the lake or reservoir is a Seepage or Drainage lake. Drainage lakes have a perennial outlet stream, while seepage do not. These two factors have the strongest influence on the plant community composition.

3.2.3 Wetlands

To date, wetland assessments have not been included in WisCALM. However, an extensive effort is underway to develop wetland plant indicators, which could be incorporated into WisCALM assessments and biocriteria in the future.

- **Wetland plants:** Assessment tools for wetland plant communities are under development. Surveys of 1100 least-disturbed and most-disturbed wetlands have been completed and used to set preliminary wetland condition thresholds for each wetland plant community by Omernik Level 3 Ecoregion. Floristic Quality Assessment metrics calculated include weighted and unweighted mean coefficient of conservatism. When all ecoregions are surveyed, the total dataset will be analyzed to determine statewide assessment thresholds where possible. A final report on development of these tools is being drafted for submittal to EPA, and more information about this effort is available at https://dnr.wi.gov/topic/Wetlands/methods.html .

3.2.4 WDNR's Bioassessment Program Evaluation

U.S. EPA has been working nationwide since 2002 to assess states' biological assessment and monitoring programs in support of biological criteria. During the course of 2013-2014, the WDNR underwent a U.S. EPA program review of its bioassessment program. The review was conducted by a U.S. EPA contractor, Midwest Biodiversity Institute, and assessed a variety of program components including the state's designated uses, monitoring capacity, assessment protocols, and biological indices. The assessment culminated in a report titled "Refining State Water Quality Monitoring Programs and Aquatic Life Uses:

Evaluation of the Wisconsin DNR Bioassessment Program" (MBI, 2014). Multiple WDNR program components were scored for several waterbody types: streams/rivers, lakes, and wetlands. The review recognized that WDNR is currently employing several biological indicators through its WisCALM assessment guidance. However, it emphasized EPA's national goal of establishing at least two biocriteria assemblages per waterbody type and strongly recommended that biocriteria be officially promulgated. The Bioassessment Program Review provided a strong endorsement for the necessity of this rule package.

3.3 WATERBODY ASSESSMENTS USING BIOLOGICAL METRICS; RELATION TO PERMITS

Under the status quo, DNR assesses biological communities using protocols documented in its WisCALM guidance. Currently, these include metrics for fish and aquatic insects. If these are not attained, a waterbody is listed for "degraded biological community". Often there is no pollutant associated with this listing, and biological impairments are not directly addressed through permit limits. Biological metrics are developed to assess overall community health, and these communities can be sensitive to a wide range of stressors outside of specific pollutants, such as habitat loss, invasive species, and dams. Biological listings are not linked to specific pollutants unless a demonstration has been made that a specific pollutant is causing the degradation. In such a case, the discharge of that pollutant could potentially be limited as a permit condition. To date, the department is not aware of any economic impacts of these listings.

- *Impairment listings*: As of the 2018 list, there are currently 228 river or stream segments listed for degraded biological community (lakes are not currently assessed for biological metrics). This is 13% of rivers/streams that have been assessed for biology.

Under narrative biocriteria, as proposed in this rule package, DNR would continue to conduct assessments under the WisCALM guidance as above. As demonstrated by several years of listings for biological metrics, we do not expect an effect to permits from these listings, even should the biological thresholds be adjusted in the future. In the rare case that a pollutant discharged by a facility is clearly and demonstrably impacting the community, an SSC for that pollutant may be developed (necessitating a comment period and EPA approval), and permit limits may be adjusted accordingly, as is appropriate if the biological community is being degraded by a discharge.

- Because DNR is currently in the process of reviewing and revising the existing metrics for fish and aquatic insects, we do expect that the biological metrics in WisCALM will be updated for the 2022 assessment cycle. We also expect to add the aquatic plant assessment tool for lakes to WisCALM, and potentially the wetland tools, as described above. These updates would be vetted first through the WisCALM public comment period and we then expect to begin a new rulemaking effort to promulgate them as numeric criteria.
- Until the tool revisions are complete, we do not yet know the number of waters that would be listed as impaired for fish or insects, but this information will be made available at that time. For addition of the plant assessments for lakes, we currenly have 656 lakes with plant surveys. Of these, 468 lakes (71%) attain the plant assessment thresholds, and 188 lakes (29%) do not attain and would be listed as impaired. Many of these would not be lakes listed as impaired for the first time, as they are already on the list as impaired for other metrics. Similar to fish or insect metrics, this plant tool is designed to reflect a broad range of stressors, such as shoreline disturbance and invasive species. Lakes with poor plant communities would typically be addressed through voluntary shoreline and lake management rather than through permit adjustments. We therefore do not expect that these biological assessments will result in economic impacts to the regulated community.

If numeric criteria are promulgated in the future, then specific thresholds for various biological communities would be established. DNR is in the process of working with EPA to develop numeric biocriteria, using the existing biological metrics in WisCALM as a foundation. The thresholds for the existing fish and insect metrics may be adjusted as needed. The discussion in the sub-bullets under narrative criteria above applies to numeric biocriteria as well as narrative biocriteria.

4. Chlorophyll *a* Criteria

High algal levels in Wisconsin's waterbodies are a top concern for Wisconsin citizens, as evidenced through public surveys and comments received during the department's Triennial Standards Review cycles, where algae-related topics consistently ranks among the public's top priorities. Algal biomass, as measured by chlorophyll *a* concentrations, relates to objectives concerning swimming and other recreational uses of lakes as well as aquatic habitat and trophic state. It is one of the most common response metrics to assess elevated phosphorus and was one of the primary metrics used in development of Wisconsin's phosphorus criteria in 2010. Chlorophyll *a* concentrations have also been used since 2012 as part of the department's standard lake assessment protocols, as detailed in WisCALM 2020. Every two years, the department uses an automated statistical package to assess all lakes in the state with sufficient chlorophyll *a* data.

Because high algal levels impact both recreational uses and aquatic life uses, chlorophyll *a* criteria are proposed for both sets of uses.

- For aquatic life use assessments, the criteria are based on mean chlorophyll *a* concentrations: mean suspended chlorophyll *a* concentrations in lakes and reservoirs shall not exceed 27 ug/L chl a, except in two-story fishery lakes, where it shall not exceed 10 ug/L.
- For recreational uses, the criteria are based on the frequency of moderate algae levels, as shown in Table 1.

These approaches are described below.

Table 1. Recreational use criteria for frequency of moderate algae levels.

Waterbody Type	Subcategory[1]: Phosphorus subcategories	Recreation Use criteria
Lakes, Reservoirs, Impounded Flowing Waters (includes cold and warm)	Impounded flowing water, Unstratified drainage, Unstratified seepage	Does not exceed 20 ug/L for more than 30% of days during the summer sampling period[2]
	Stratified drainage, Stratified seepage	Does not exceed 20 ug/L for more than 5% of days during the summer sampling period[2]
	Stratified two-story fishery	

[1] Terms used for waterbody types and subcategories are defined in s. NR 102.03. These criteria do not apply to streams or rivers.
[2] Summer sampling period is July 15 to September 15.

4.1 CHLOROPHYLL *A* CRITERIA TO PROTECT RECREATION USES

For recreational uses such as swimming, boating, and aesthetics, the criteria for chlorophyll *a* is based on the frequency of moderate algae levels. This section describes how moderate algae levels are defined, and the selection of a frequency threshold for different lake types.

4.1.1 Defining moderate algae levels

Lake recreational chlorophyll *a* criteria are designed to protect primary contact recreation (swimming). Since 2002, Wisconsin's citizen lake monitoring network has collected over 10,000 chlorophyll *a* samples and corresponding user perception ratings of water quality. We conducted a statistical analysis of the relationship between user perception and chlorophyll *a* concentration to help identify appropriate criteria. This enabled us to determine a chlorophyll *a* threshold at which conditions decline to an extent that users experience decreased enjoyment, but before substantial numbers would not swim.

Citizen monitors rate the condition of each lake and their enjoyment of it on the day they sample water quality. Citizens do not know the chlorophyll *a* concentration results at the time they rank the lake condition in one of the following five categories:

1 = Beautiful, could not be any nicer
2 = Very minor aesthetic problems; excellent for swimming and boating enjoyment
3 = Swimming and aesthetic enjoyment of lake slightly impaired because of high algae levels
4 = Desire to swim and level of enjoyment of lake substantially reduced because of algae; would not swim, but boating OK
5 = Swimming and aesthetic enjoyment of lake substantially reduced because of algae levels

These rankings were used in conjunction with the chlorophyll *a* data collected on the day of the survey. As described in the statistical analysis section below, we used a logistic regression model to evaluate the relationship between the subjective perception ratings and measured chlorophyll *a* concentration (M. Diebel, WDNR, unpublished analysis, 2016). The analysis shows that subjective perception of water quality is strongly related to measured chlorophyll *a* concentration (Figure 3). We used the results to propose a definition of "moderate algae" levels of $\geq$ 20 ug/L chl *a*.

Proposed chlorophyll *a* criteria may be determined by a) identifying inflection points in the relationship at which half the users perceive a particular condition, and/or b) specifying a target frequency of lake user perception (e.g., 90% of lake users view the water as suitable for swimming). We based our proposed definition of "moderate algae" at $\geq$ 20 ug/L chl *a* on both of these factors, which provided two main findings:

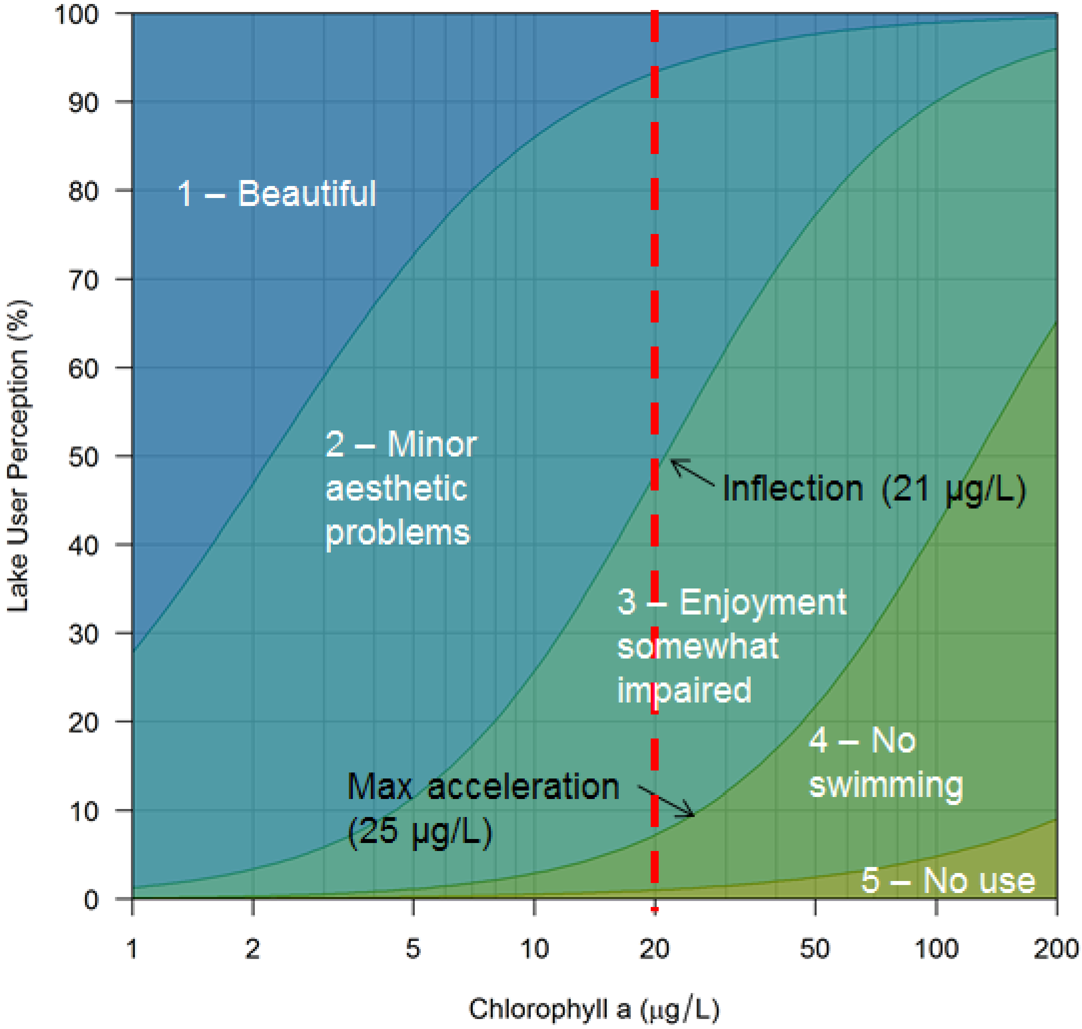
- The point at which half of users say their enjoyment is somewhat impaired due to algae is at 21 ug/L chl *a*. This is shown in Figure 3 as the inflection point for the line indicating the upper edge of category 3. Below this concentration, the majority of users indicate that algae levels do not inhibit their use of the waterbody; whereas above this concentration a majority of users experience decreased enjoyment and recreation.
- The point at which most users (over 90%) would still swim, but just before a rapid increase in the proportion of users who would *not* swim, is at 25 ug/L chl *a*. This is shown on Figure 3 as the point of maximum acceleration for the line indicating the upper edge of category 4. This establishes the threshold before the point at which swimming becomes significantly inhibited.

The inflection point for "Category 3 – Enjoyment somewhat impaired" (21 µg/L) and the point of maximum acceleration for "Category 4 – No swimming" (25 µg/L) are nearly equal, and a criterion in this range could be translated into the following narrative justification: "Half of lake users perceive some impairment to their enjoyment and recreation due to algae, but over 90% of users would still swim." Rounding these values down to 20 µg/L, the draft criterion, provides a margin of safety. Importantly, once this point is exceeded, the perceived impacts of algae increase rapidly and users are much less inclined to swim.

By setting Wisconsin's frequency criterion to limit moderate algae levels of 20 ug/L chl *a*, we are also protective against "severe" and "very severe" blooms, restricting these to occur a very small percent of the time.

This analysis only evaluates instantaneous perception of water quality, not the cumulative effects of persistent algal blooms on perceived suitability for recreation. The allowable exceedance frequency is discussed in the following section.

Figure 3. Plot of fitted relationships between chlorophyll *a* concentration and Wisconsin lake user perception of water quality.



Statistical analysis

The data used in the analysis were all chlorophyll *a* samples collected from the top 2 m of the water column in Wisconsin lakes and reservoirs during the period July 8 – Sept 22 (WisCALM chlorophyll *a* assessment period) from 2002[1] to 2016. Multiple values from the same station and date were averaged, and samples without a corresponding user perception rating were excluded.

The statistical model is a set of mixed effects logistic regressions, one for each perception level, where the response variable is a binary (0/1) of that perception level or higher (i.e., worse) and the predictor is

[1] 2002 is when the current laboratory procedure (chlorophyll *a* by fluorescence) became the standard.

log(chlorophyll). Station ID was included as a random effect on both the intercept and slope of log(chlorophyll) to account for variance among lakes and stations in the relationship between chlorophyll *a* and user perception. The models were fit using the glmer function in the R package lme4 with the following call:

```
glmer(IMP ~ log(CHL) + (1 + log(CHL) | STATION_ID), mdata, family=binomial, nAGQ=0,
control=glmerControl(optimizer = "nloptwrap"))
```

Variance in the fitted relationships was assessed by selecting bootstrap sample sets with replacement and refitting the model 500 times. The control arguments in the model call were used to speed model fitting to allow use of the bootstrap procedure. These controls gave identical parameter estimates to the default controls. Models were fit for nine lake classes and for all lakes combined. The following discussion of potential criteria is based on the "all lakes" model. The nine lake classes did not exhibit enough variation to warrant separation of results based on lake class.

The "all lakes" model shows that subjective perception of water quality is strongly related to measured chlorophyll *a* concentration (Figure 3). It is appropriate to plot this kind of relationship on a log-linear plot because human perception of most stimuli scales linearly with the log of the stimulus (Fechner's Law, see Smith and Perrone 1996 for evaluation of this principle to water clarity). Proposed chlorophyll *a* criteria may be identified by either a) specifying a target frequency of lake user perception (e.g., 90% of lake users view the water as suitable for swimming), or b) identifying inflection points in the relationships that signify changes in the unit response to a unit stimulus. Critical points in a logistic function are the inflection point (PI), where the slope is maximal, and the points of maximum and minimum acceleration (PAA[2] = 9% and PDA = 91% of function maximum), which are where the function breaks from its lower and upper plateaus to its growth phase (Mischan et al. 2011). In application to the user perception curves, the PI is where half of the users perceive a particular condition, and the PAA is a breakpoint, above which the rate of increase in perception is highest. The PI for "3 – Enjoyment somewhat impaired" (21 µg/L) and the PAA for "4 – No swimming" (25 µg/L) are nearly equal, and a criterion in this range could be translated into the following narrative justification: "At least half of lake users do not perceive any significant water quality problems and the water quality is suitable for swimming for the vast majority of users." Rounding these values down to 20 µg/L, the draft criterion, would provide a margin of safety. This analysis only evaluates instantaneous perception of water quality, not the cumulative effects of persistent algal blooms on perceived suitability for recreation. The allowable exceedance frequency is discussed in the following section.

Consistency with previous protocols and research

The findings of Wisconsin's user perception survey and resulting selection of a "moderate algae" level of 20 ug/L chl *a* are consistent with Wisconsin's previous thresholds and assessment protocols and earlier research done by other parties, as described below. The 2016 analysis of Wisconsin user perception data supported the continued use of this threshold.

- A chlorophyll *a* threshold of 20 ug/L chl *a* was previously used by WDNR to develop Wisconsin's statewide phosphorus criteria for lakes, promulgated in 2010. During development of the statewide phosphorus criteria, the threshold of 20 ug/L chl a was based on Minnesota's work, discussed below. WDNR has also used this concentration in assessment protocols since the promulgation of P criteria in 2010.

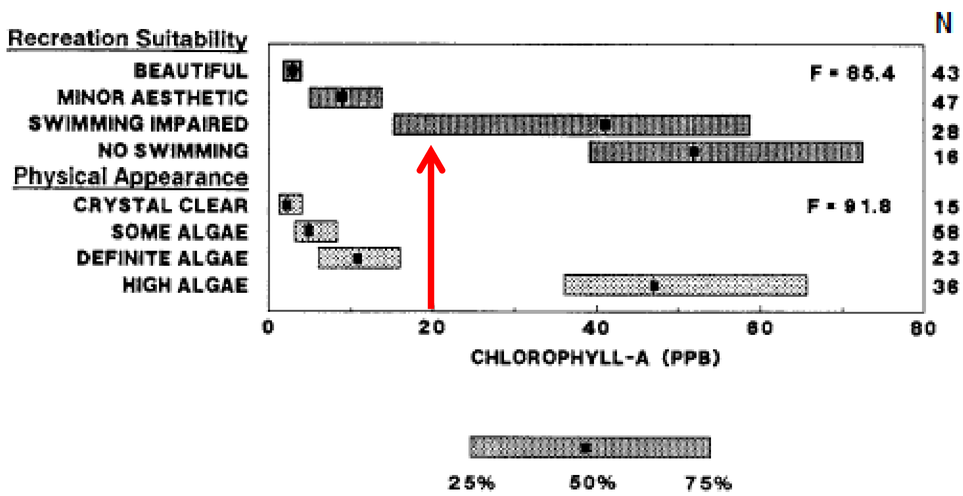
- WDNR's definition of a "moderate algae" level directly corresponds with the Minnesota Pollution Control Agency's (MPCA's) definition of a "nuisance" algal bloom. Minnesota conducted an earlier

[2] In the paper cited, PAA stands for Point of Asymptotic Acceleration; PDA stands for Point of Asymptotic Deceleration. Letters of the acronym are rearranged with the A for Asymptotic last (Mischan et al. 2011).

study that surveyed user perceptions of lakes' recreational suitability and physical appearance (Heiskary and Walker, 1988). The study coupled user perceptions with simultaneously collected data on phosphorus, chlorophyll *a*, and Secchi depth. MPCA defined four algal bloom categories during their development of phosphorus criteria for Minnesota lakes: a "mild bloom" is greater than 10 ug/L; a "nuisance bloom" is greater than 20 ug/L; "severe nuisance bloom" is greater than 30 ug/L; and a "very severe nuisance bloom" is greater than 40 ug/L chl *a* (Heiskary and Wilson, 2008).

As shown in Figure 4, a chlorophyll *a* concentration of 20 ug/L corresponds with the lower end of perceived swimming impairment, and is between a physical appearance of "definite algae" and "high algae". This study was used by both the Minnesota Pollution Control Agency and the Wisconsin DNR in setting phosphorus criteria for lakes.

Figure 4. Excerpt from Figure 3 in Heiskary and Walker's 1988 paper showing results of user perception surveys of a range of chlorophyll *a* concentrations. Interquartile ranges of measurements in each response category. Legend: N = number of observations; F = variance ration (among-group mean square/within-group mean square) derived from one-way analysis of variance on logarithmic scales.



- The threshold of 20 ug/L chlorophyll *a* is also consistent with an extensive analysis of Wisconsin lake data by Lillie and Mason, published in 1983. This analysis recommended six categories for chlorophyll *a* in relation to water clarity (Figure 5). As shown in Figure 5, a concentration of 20 ug/L chlorophyll *a* as a moderate algae level corresponds to the lower (better) end of the "Poor" category. The frequency criteria provided here would restrict this poorer level of water quality to a given percentage of the summer.

Figure 5. Excepted from Lillie and Mason (1983), Table 19. Apparent water quality based on chlorophyll *a* and water clarity as related to the Carlson Trophic State Index.

Chlorophyll *a* (µg/l)	Apparent Water Quality	Approximate Water Clarity Equivalent (m)	Approximate TSI* Equivalent
<1	Excellent	>6	<34
1-5	Very Good	3.0-6.0	34-44
5-10	Good	2.0-3.0	44-50
10-15	Fair	1.5-2.0	50-54
15-30	Poor	1.0-1.5	54-60
>30	Very Poor	<1.0	>60

*Based on Carlson (1977).

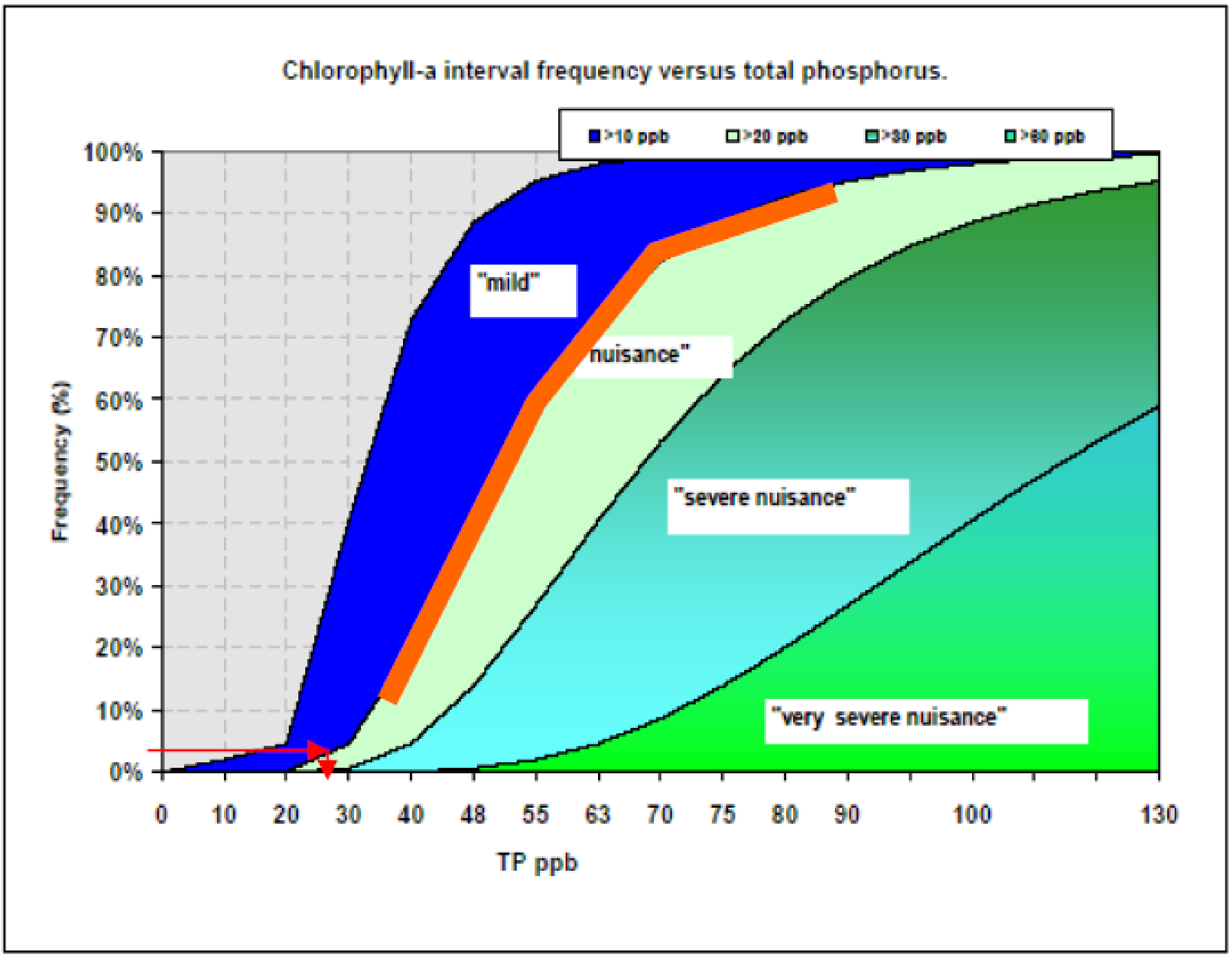
4.1.2 Frequency of moderate algae levels

This assessment protocol is based on the percent of days (frequency) during the summer sampling season that a lake experiences moderate algae levels. This approach recognizes that algal concentrations are episodic in nature and that higher levels naturally occur a certain percent of the time. Because of this episodic nature, a frequency measure is more appropriate for assessing recreational opportunity than a mean concentration over a longer timeframe.

Deep lakes

The proposed recreational use criterion for deep lakes is that moderate algae levels (20 ug/L chlorophyll *a*) shall not occur more than 5% of days during the summer sampling season. This threshold was one of the primary endpoints used for development of the statewide phosphorus criteria in 2010 (Phosphorus Technical Support Document, 2010). Figure 6 was used in Wisconsin's Phosphorus Technical Support Document to show that 5% frequency corresponds to ~28 ug/L phosphorus. This was rounded up to a criterion of 30 ug/L TPfor deep lakes, which should result in moderate algae less than 5% of the summer and severe blooms less than 1% of the time. The figure was originally developed from a study on user perceptions of lake recreation suitability in Minnesota (Heiskary and Walker, 1988), and was also used as a basis for Minnesota phosphorus criteria for lakes (Minnesota Pollution Control Agency, 2005).

Figure 6. Frequency of moderate algae levels (formerly termed "nuisance" algal conditions in the 2010 Phosphorus Technical Support Document) relative to total phosphorus concentrations.

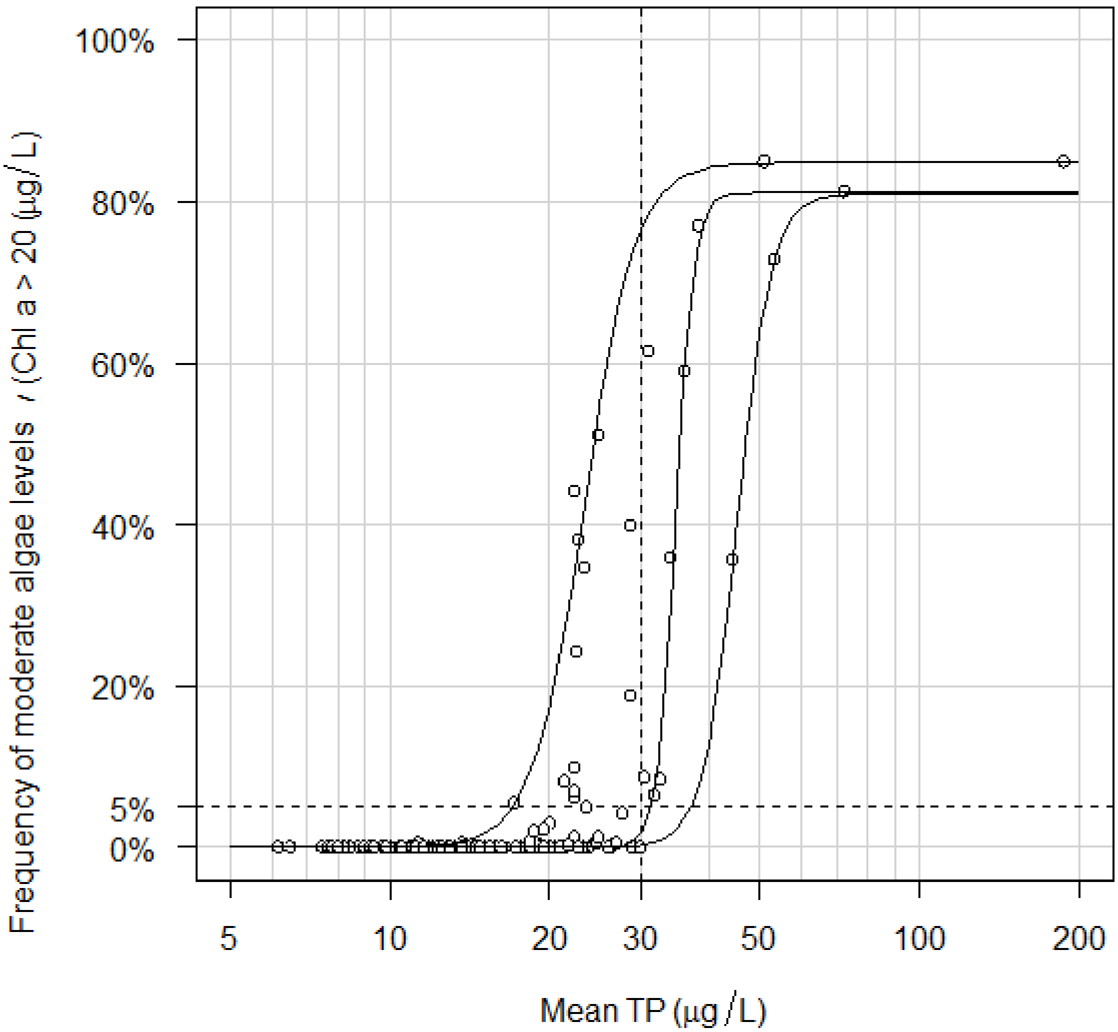


Sources: Reprinted from Wisconsin's 2010 Phosphorus Technical Support Document. Graph shows paired phosphorus and chlorophyll *a* measurements from 641 lakes as presented on page 25 of "Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria", Third Edition, September 2005, Minnesota Pollution Control Agency. The development of the chart is described in the article by Heiskary and Walker, titled "Developing nutrient criteria for Minnesota lakes" and published in Lake and Reservoir Management 4:1-9, 1988. Arrows and highlight were added in WI's 2010 Phosphorus Technical Support Document.

As part of more recent efforts to develop phosphorus response indicators, we conducted a quantile regression analysis of Wisconsin's deep lakes comparing phosphorus to the frequency of moderate algae levels (Figure 7). The dataset for this analysis included all deep lakes in the state that had six or more TP and chlorophyll *a* samples (416 lakes). 50% of deep lakes at the deep lake TP criterion of 30 µg/L TP attained a frequency of 5% moderate algae levels. This analysis shows that a typical lake that meets the TP criterion will also meet the chlorophyll *a* criterion.

The frequency of days with moderate algae levels is not calculated as a fraction of total samples taken, but is instead estimated by fitting a distribution to all of the existing chlorophyll *a* data. For each lake, the non-central T-distribution is fit to at least 6 chlorophyll *a* concentrations and the probability of exceeding 20 ug/L chl-a is estimated from this distribution. A 90% confidence interval for frequency of moderate algae levels is also estimated, which accounts for sample size and chlorophyll *a* variability.

Figure 7. Quantile regressions (5%, 50%, and 95%) showing relationship between phosphorus concentration and frequency of moderate algae levels (20 µg/L) in Wisconsin's deep lakes. Dashed lines indicate the established phosphorus and proposed chlorophyll *a* criteria.



Shallow lakes

Wisconsin's statewide phosphorus criteria Technical Support Document does not specify the frequency of moderate algae levels appropriate for shallow lakes nor does Wisconsin have user perception surveys to determine a publicly 'acceptable' frequency of moderate algae for shallow lakes. Further, algal blooms are a natural and expected occurrence on many shallow lakes. Therefore, we employed a reference lake approach to determine the frequency of moderate algae levels expected in shallow lakes least disturbed by anthropogenic stressors. We then compared the frequency of moderate algae in shallow reference lakes to all shallow lakes.

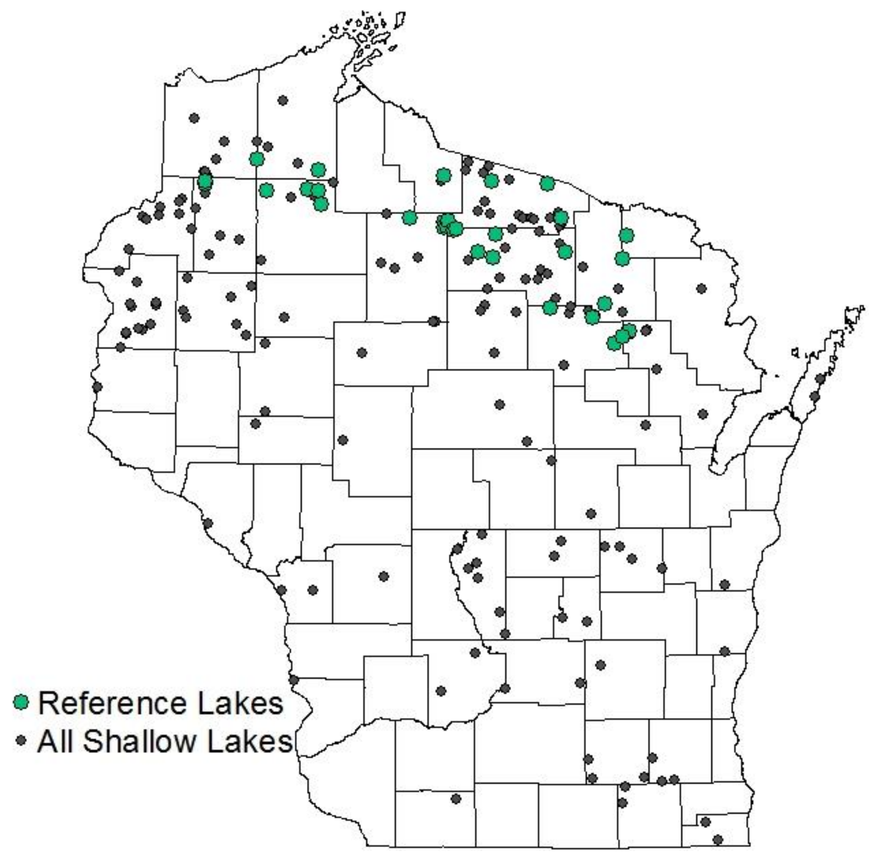
We compiled a data set on all shallow lakes in Wisconsin that had at least 6 total phosphorus and 6 chlorophyll *a* samples (usually paired) from the deepest point of the lake (n=184). We analyzed the landcover (2006 National Landcover Dataset) in the entire upstream watershed of all 184 lakes and defined reference lakes as having minimal urban (Developed, Open Space; Developed, Low Intensity; Developed, Medium Intensity; Developed, High Intensity) and agricultural (Pasture/Hay; Cultivated Crops) land cover (sum of urban and agricultural land covers < 5%). The reference list based on land cover was further screened. Lakes were removed from the reference list based on regional biologists' knowledge of the lake

(Table 2). The final set of 32 reference lakes are all located in northern Wisconsin, an unintended consequence of the land cover criteria used to define reference lakes (Figure 8).

Table 2. Justification for removing lakes from the shallow reference dataset even though land cover criteria were met (<5% urban and agricultural land cover in the upstream watershed).

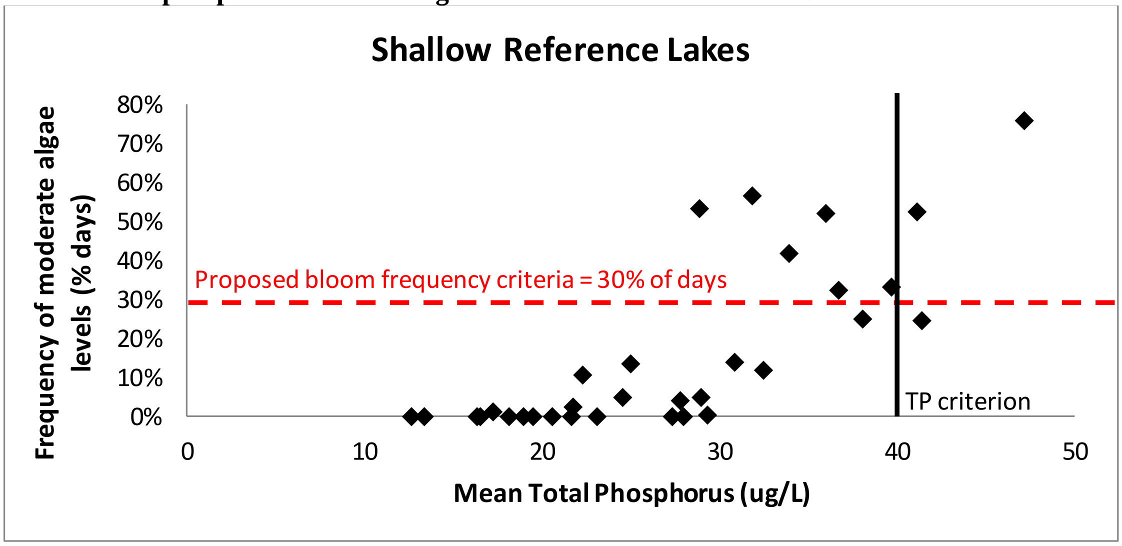
Lake Name	WBIC	Reason for removing from Reference dataset
Teal Lake	2417000	Carp reported present (carp resuspend nutrients in the sediment and shift lakes to algal dominated state)
Rolling Stone	389300	harvesting aquatic plants; impacts likely due to shoreland development and drainage from wetlands (possibly higher phosphorus soils)
Minong Flowage	2692900	major drawdown from 2013-2014
Musser Flowage	2245100	moderate development; managing for curly leaf pondweed
Cranberry	1603800	very developed, poor shoreline habitat, high runoff
Crane	388500	harvesting aquatic plants; impacts likely due to shoreland development and drainage from wetlands (possibly higher phosphorus soils)

Figure 8. Locations of reference and all other shallow lakes with at least 6 chlorophyll *a* and 6 total phosphorus samples from the deepest station.



The proposed recreational use criterion for shallow lakes is that shallow lakes shall not experience moderate algae levels (20 ug/L chlorophyll *a*) more than 30% of days during the summer sampling season. This criterion was determined by calculating the 75th percentile of moderate algal frequency in all shallow reference lakes, which was 27%. Stated differently, 75% of shallow reference lakes have moderate algae levels less than 27% of the time. Given the uncertainty in selecting reference lakes, we rounded up to 30% for the shallow lake criterion (Figure 9).

Figure 9. Statistically calculated frequency of summer moderate algae levels (chlorophyll *a* > 20 ug/L) in relation to mean total phosphorus levels among a set of shallow reference lakes.



Compared to all shallow lakes, shallow reference lakes show a similar relationship between mean total phosphorus and frequency of moderate algal levels (Figure 10). We observed the following patterns:

- The probability of moderate algae levels increases rapidly at 30-40 ug/L total phosphorus and remains high when TP > 40 ug/L (Figure 10). A large majority of both shallow reference lakes and all shallow lakes meeting the TP criterion experience algal blooms less than 30% of the time (Figure 11).
- Some reference lakes have moderate algae more than 30% of the time; one reference lake had moderate algae 76% of days (Figure 9). The high rates of algal blooms in a few reference lakes could be due to unknown anthropogenic stressors or could be naturally high.
- Despite high frequency of algal blooms in a handful of reference lakes, the proposed criterion is not too restrictive. Most shallow lakes with moderate algae more than 30% of the time also exceeded the Aquatic Life chlorophyll *a* criterion (27 ug/L, Figure 10) and the total phosphorus criterion (40 ug/L, Figure 11).
- All lakes exceeding Aquatic Life chlorophyll *a* criteria have moderate algae more than 58% of the time. This provides good separation between lakes exceeding the proposed Recreation criteria for frequency of moderate algae levels versus the Aquatic Life chlorophyll *a* criterion (Figure 10).

Figure 10. Probability of moderate algae levels (chlorophyll *a* >20 ug/L) in shallow reference lakes and in all shallow lakes that meet and exceed the Aquatic Life chlorophyll *a* criteria (27 ug/L chlorophyll *a*).

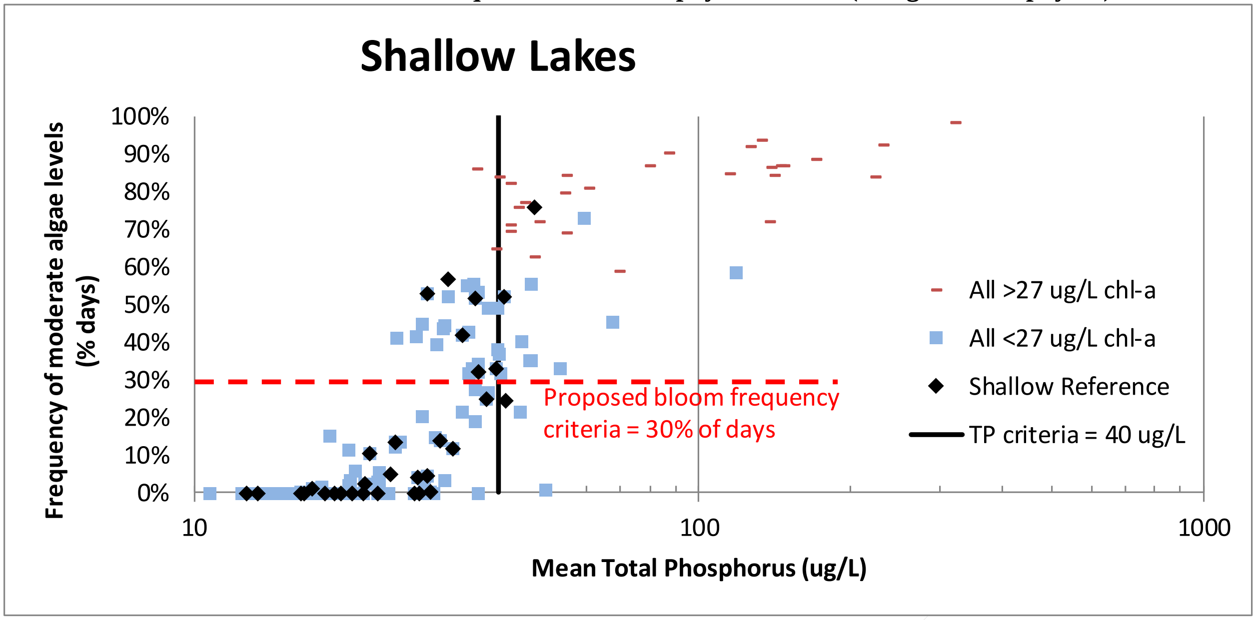
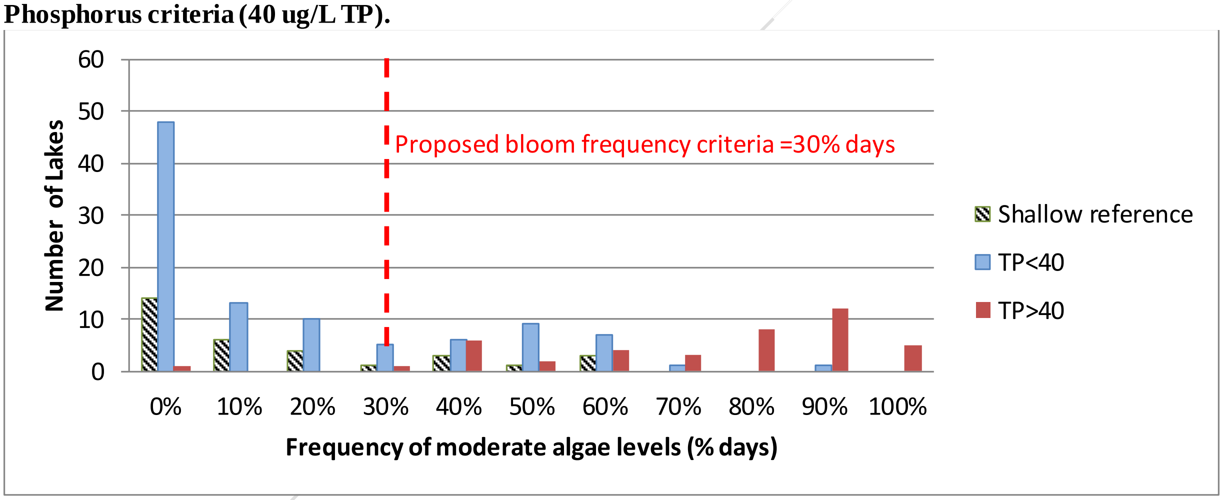


Figure 11. Number of lakes that have moderate algae levels 0 to 100% of the time. Shallow reference lakes are plotted separately from all other shallow lakes, which are divided amongst those that meet or exceed the Total Phosphorus criteria (40 ug/L TP).



The number of lakes listed as impaired for recreational chlorophyll *a* also depends on the confidence interval (CI) of the probability of chlorophyll *a* exceeding 20 ug/L. The application of the confidence interval approach is described briefly later in this section, and also in section 2.1.2. We counted the number of lakes that would clearly meet (90% confidence interval below criteria), may meet (median below criteria but 90% CI overlaps with criteria), may exceed (median above criteria but 90% CI overlaps with criteria), or clearly exceed (90% confidence interval above criteria) the recreational chlorophyll *a* criterion (Table 3). Most lakes clearly meet or exceed the criterion. For those with unclear assessment results (may meet or may exceed), an additional year of sampling is done to increase certainty; after that point, if results are still unclear the attainment decision is based on whether the mean is above or below the criterion.

Table 3. Number of shallow lakes that will meet or exceed the recreational chlorophyll *a* criteria given the 90% confidence intervals of the median probability of exceeding 20 ug/L chlorophyll *a*. Lakes are also tallied by the total phosphorus criterion (40 ug/L and the Aquatic Life chlorophyll *a* criterion (27 ug/L).

Lake Group	Meet	May Meet	May Exceed	Exceed
Shallow Reference	21	3	4	4
All Shallow Lakes	68	10	21	43
TP < 40 ug/L	67	9	13	11
chl *a* < 27 ug/L	68	10	21	13
TP > 40 ug/L	1	1	8	32
chl *a* > 27 ug/L	0	0	0	30

In summary, the recreational use chlorophyll *a* criterion for shallow lakes is the 75th percentile of a shallow reference lake data set and is consistent with previous WisCALM guidance. Most lakes meet the criterion and most lakes that do not also exceed aquatic life chlorophyll *a* and TP criteria. This recreation criterion is more stringent than the aquatic life chlorophyll *a* criterion and will thus identify some lakes showing signs of phosphorus impairment before they exceed the phosphorus and/or aquatic life chlorophyll *a* criterion.

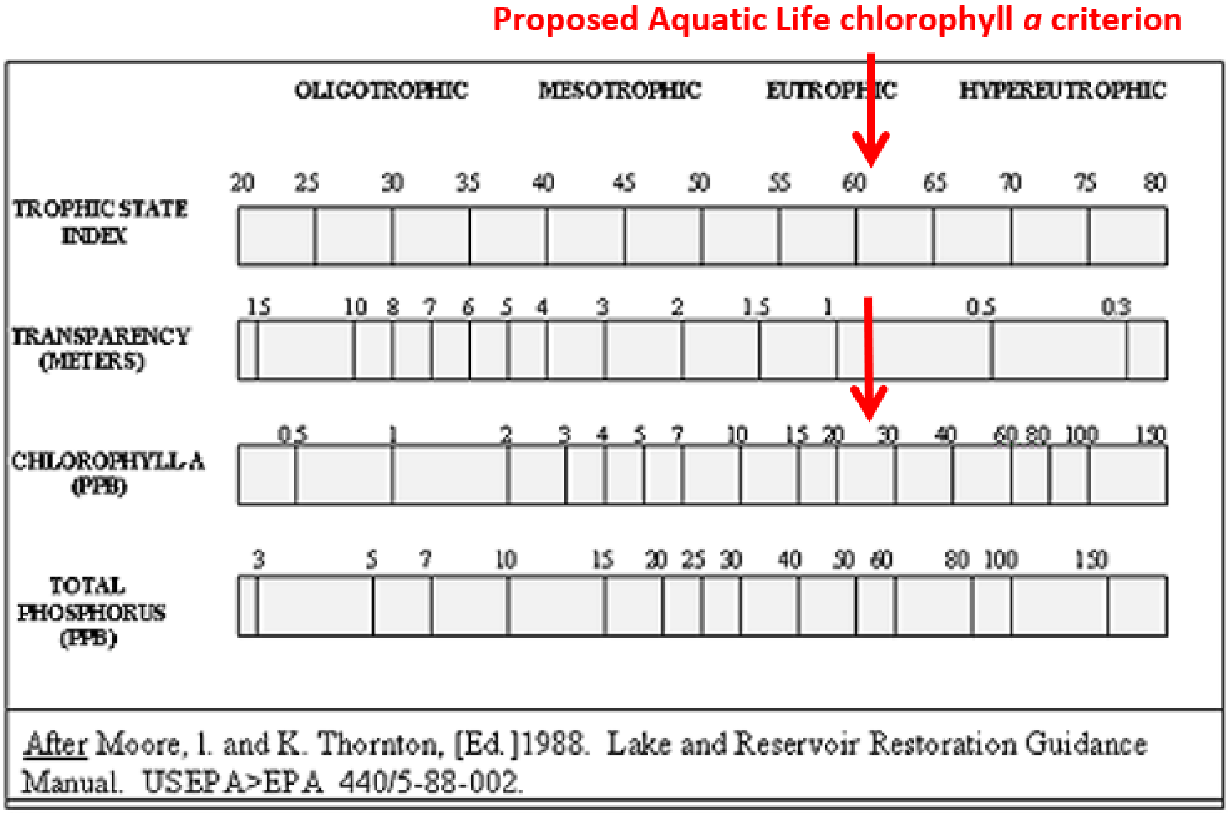
4.2 CHLOROPHYLL *A* CRITERIA TO PROTECT AQUATIC LIFE USES

The statewide lake phosphorus criteria specified in ch. NR 102.06 were set based on numerous factors to protect lake designated uses. As discussed above, recreational uses in lakes, primarily swimming, are impacted by algal blooms at a relatively low level of phosphorus. Aquatic life communities, particularly fish, are typically not impacted until higher levels of chlorophyll *a* are reached. This is because they are affected relatively little by rising levels of chlorophyll *a* until the lake 'flips' from a plant-dominated state to an algal-dominated state, at which point high levels of chlorophyll *a* impact visual feeding, reduce aquatic plants needed for habitat, and impact availability of food sources. In order to assess support of recreational uses and aquatic life uses separately, the department is proposing chlorophyll *a* criteria for aquatic life that represent the threshold at which these respective uses are not attained.

Deep and Shallow Lakes:
The recommended Aquatic Life chlorophyll *a* criteria for all lakes except 2-story fishery lakes is 27 ug/L. This threshold is at the high end of eutrophic, but has not yet become hyper-eutrophic. Along the Trophic State Index (TSI) gradient, a TSI value of 63 corresponds with a concentration of 27 ug/L chlorophyll *a* and 60 ug/L total phosphorus (Figure 12, Carlson 1997). At this stage, the lake still may be restored to a clear water state, as it is before the point at which shallow lakes shift from an aquatic plant dominated to an algal dominated state (Jeppesen et al. 1990). Because it is extremely difficulat to shift a lake back to a plant dominated, clear water state once it has reached an algal dominated state, the criterion should be low enough to prevent this state shift.

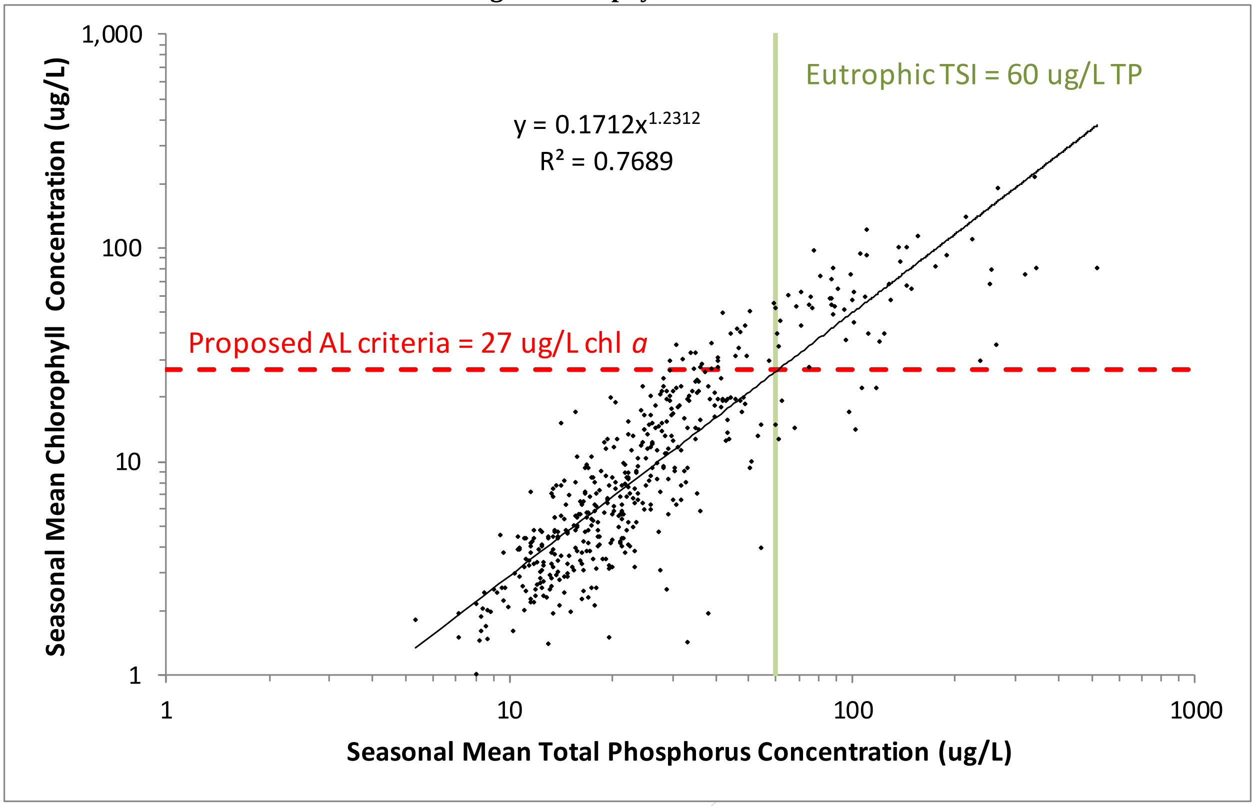
The following equations were used to equate chlorophyll *a* and TP concentrations to TSI values:
$TSI_{CHL} = 9.81 \ln (CHL) + 30.6$
$TSI_{TP} = 10 (6 - ((\ln(48/TP))/\ln(2)))$
Where: TSI = Trophic Status Index, CHL = Chlorophyll-*a* concentration (µg/L), TP = total phosphorus concentration (µg/L), ln = natural log

Figure 12. Continuum of lake trophic status in relation to Carlson Trophic State Index. The proposed criterion of 27 ug/L chl a (63 TSI) is at the upper end of eutrophic.



To ensure that the proposed criterion based on the general TSI gradient applies to Wisconsin lakes, we fit a power relationship to mean total phosphorus and chlorophyll *a* (at lakes with at least 6 samples of chlorophyll *a* and TP taken at the deepest point of the lake). The chlorophyll *a* value at 60 ug/L TP was 27 ug/L (Figure 13). We also fit separate power relationships for shallow versus deep lakes, but decided to pool them because the relationship was the same. Thus, we confirmed that the relationship between phosphorus and chlorophyll *a* is similar in Wisconsin lakes to lakes that contributed to the Trophic State Index.

Figure 13. Mean total phosphorus (TP) and chlorophyll *a* in all lakes. The TP concentration of 60 ug/L representing a eutrophic state is shown as a green vertical line. The proposed Aquatic Life (AL) chlorophyll *a* criterion is a dashed horizontal line at 27 ug/L chlorophyll *a*.



In summary, the proposed Aquatic Life chlorophyll *a* criterion for deep and shallow lakes lies at the upper range of eutrophic. While initially based on the Carlson Trophic State Index, the data analysis above demonstrates that the general TSI gradient applies to Wisconsin lakes. Finally, chlorophyll *a* criteria were previously in guidance, but will now be codified.

Two-Story Lakes:
The proposed chlorophyll *a* criterion for two-story fishery lakes is 10 ug/L. TSI values that cause significant hypolimnetic oxygen depletion should be used as the threshold for two-story lakes because this habitat component is critical for maintaining coldwater fisheries. This value will be highly dependent upon the lake's morphometry. Hypolimnetic oxygen demand is largely from the sediment; therefore, the greater the ratio of *sediment area to hypolimnetic water volume* the higher the hypolimnetic oxygen demand. That makes setting this threshold very difficult. A conservative TSI value of 53, upper end of mesotrophic, is recommended. The chlorophyll *a* concentration for two-story fishery lakes that is equivalent to a TSI of 53 is 10 ug/L. Additional research on these relationships may be useful.

4.3 ASSESSMENT DECISIONS

The statistical methods for calculating the chlorophyll *a* concentrations and the number of days in the sampling season that exceed 20 ug/L chlorophyll *a* are described in detail in WisCALM 2020 in Section 4.4 to 4.6.

For the Aquatic Life chlorophyll *a* criterion, samples for each lake are aggregated into a "grand mean" and are compared against the criterion. Due to variability in water quality samples, the confidence interval approach as described in section 2.1.2 of this document and in WisCALM is applied to determine if more samples are needed before making an assessment decision.

For the Recreational use criterion measuring frequency of moderate algae levels, the confidence interval approach is applied in a very similar way except that instead of comparing the grand mean against the criterion concentration, the percent of days exceeding 20 µg/L is compared against the percent of days established in the criterion.

If the determination is unclear—either "May Exceed" or "May Meet"—additional samples are required to shrink the confidence interval. Typically an additional year of sampling is done to increase certainty; after that point, if results are still unclear the attainment decision is based on whether the mean is above or below the criterion.

5. Dissolved oxygen & Oxythermal Habitat Criteria

This rule package contains updates to the existing dissolved oxygen critera and creates new oxythermal criteria for a special class of ~180 lakes that contain coldwater fish, called two-story fishery lakes.

5.1 DISSOLVED OXYGEN

The existing DO language specifies that it applies to trout waters; however, non-trout coldwater species also require higher DO and therefore the language is being adjusted to cover non-trout cold waters under the Cold DO criterion. As such, the existing DO criterion for cold waters will be applied to the following Designated Uses: Cold streams (which includes further subcategories called "Natural Communities" of Cold and Cold Transition Headwater and Cold Transition Mainstem streams), Cold lakes except for two-story fishery lakes (see below), and Great Lakes. Language was also adjusted to protect early life stages of fish until they leave their gravel nests, beyond the fall spawning season. These updates support the U.S. EPA's national recommendation that cold water DO criteria apply to any cold water systems for which higher DO is necessary:

> **U.S. EPA's National Recommended Ambient WQC for DO:** *Criteria for coldwater fish are intended to apply to waters containing a population of one or more species in the family Salmonidae or to waters containing other coldwater or coolwater fish deemed by the user to be closer to salmonids in sensitivity than to most warmwater species. Some coolwater species may require more protection than that afforded by the other life stage criteria for warmwater fish and it may be desirable to protect sensitive coolwater species with the coldwater criteria.*
> (U.S. EPA Ambient Water Quality Criteria for Dissolved Oxygen (EPA 440/5-60-003), April 1986)

In the existing code, the coldwater DO criteria of 7 mg/L to protect spawning also applied to class III trout waters. However, this is proposed for removal because class III trout waters do not have naturally reproducing trout.

The existing DO criterion of 5 mg/L will apply to warmwater streams and rivers, and all lakes other than those specified above. This is consistent with the status quo.

This rule relocates certain dissolved oxygen criteria from ch. NR 104 to s. NR 102.04(4), so that all DO criteria are located in the same part of the code in ch. NR 102. The relocated criteria are the existing dissolved oxygen criterion of 3 mg/L for limited forage fish waters and 1 mg/L for limited aquatic life waters, diffuse surface waters, and wastewater effluent channels.

Existing introductory language in NR 102.04(4) provides an exception for natural conditions. This exception may be applied to waters with either higher or lower than typical natural DO concentrations. Note that natural conditions for DO fluctuate over a 24 hour diurnal cycle, with highest DO in late afternoon, and lowest just before dawn.

5.2 OXYTHERMAL HABITAT FOR TWO-STORY FISHERY LAKES

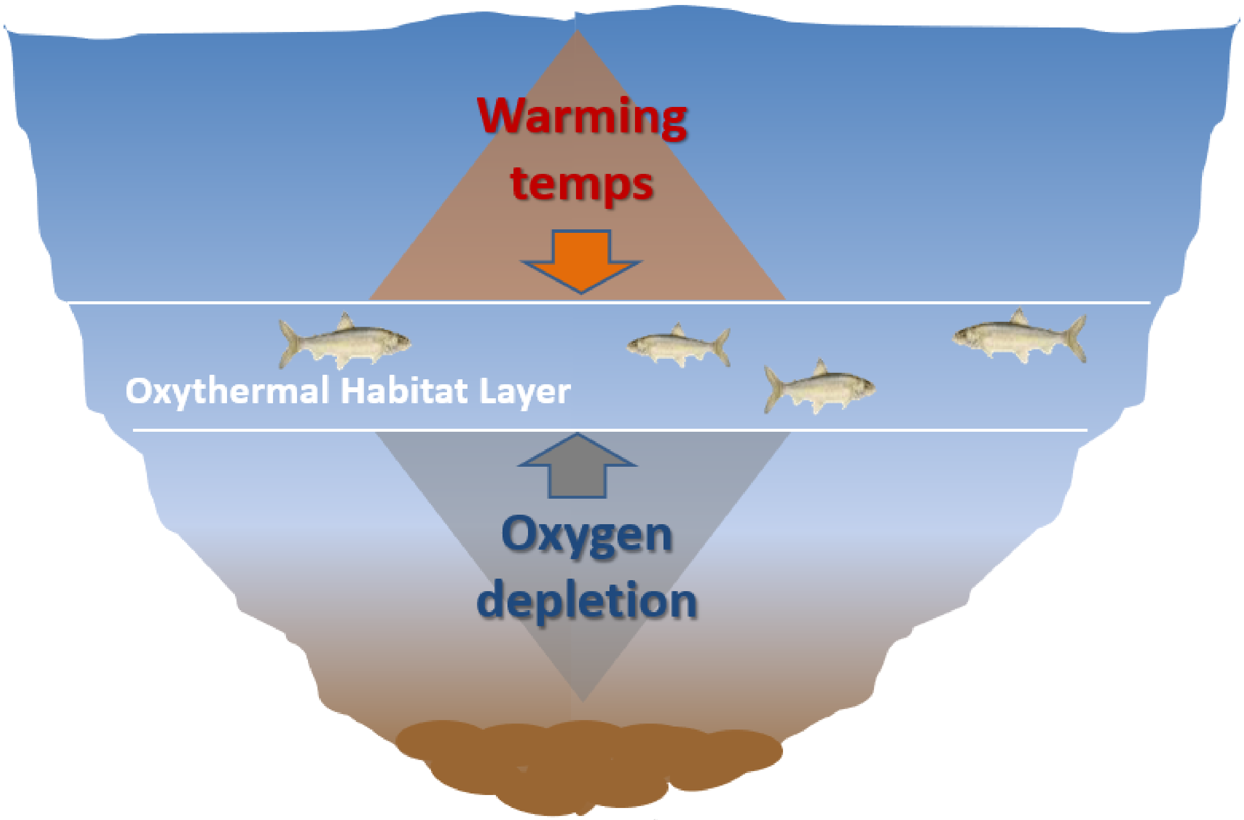
Two-story fishery lakes have coldwater fish species, but their requirements differ significantly from coldwater streams and from other lakes. Because coldwater fishes have specific DO and temperature needs that occur within a narrow vertical habitat range, their criteria combine oxygen and temperature measurements and are called oxythermal layer criteria.

Definition of Two-Story Fishery Lake
A two-story fishery lake is defined in the code as a lake greater than 5 acres in size that is always stratified in the summer, with the potential for an oxygenated hypolimnion, that has documentation since 1975 of a population of cold water fish species such as cisco, whitefish, or trout that is sustained through natural reproduction or long-term active stocking with year-to-year survival. This definition is revised slightly from the existing definition to provide additional clarity.

Habitat quantity concepts for two-story fishery lakes
For most cold waters of the state, the dissolved oxygen metric used to determine support of the fishery is a DO concentration of 6 mg/l. However, for two-story fisheries, a DO concentration alone is not the best way to represent the habitat characteristics needed to support the fishery. Cisco, whitefish and other coldwater fishes need a band of water that has both cold enough temperatures and high enough oxygen for them to survive. At the beginning of summer, the entire water column usually has both, but by the end of summer, temperatures in the surface water may be too warm and the DO near the bottom may be too low, squeezing the fish into a narrow band along the thermocline where they can survive (Figure 14). Therefore, a measure that represents the overall quantity of suitable habitat by combining both DO and temperature is a more useful metric for assessing support of the two-story fishery.

The concepts and methods used in the oxythermal layer approach are described in Lyons, et. al (2017), in which cisco data from Wisconsin two-story fishery lakes are analyzed and a metric called "cisco layer thickness" is developed. The same methods were then applied to whitefish and lake trout to develop a set of criteria that are suitable for all three coldwater species found in Wisconsin's two-story fishery lakes. Earlier work done in Minnesota developed a similar measurement called "TDO3" for their two-story fishery lakes. TDO3 is a vertical measurement of the water temperature (T) at which the dissolved oxygen (DO) concentration is 3.0 mg/l. WDNR's work built from that concept and applied a variation of this method whereby a certain *quantity* of habitat is required which attains an appropriate DO (WDNR used 6 mg/L rather than 3) and temperature. This has the advantage of requiring a certain depth of habitat to ensure survival, rather than establishing a single point at which the criterion must be met as in the TDO3 approach.

Figure 14. In late summer, coldwater fish can live only in the band in which there is sufficient dissolved oxygen and cool enough temperatures, termed the oxythermal layer.



Calculating species' DO and thermal requirements

Each fish species has specific oxygen and thermal ranges suitable to its survival. WDNR assessed species information is from recent (2011-2015) data from a majority (~155) of Wisconsin's two-story fishery lakes combined with research done in Minnesota. The oxythermal criteria for each species is based on the species' upper temperature limit and a protective DO limit of 6 mg/L. The data assessed indicated the following:

- Cisco, whitefish, and lake trout can survive oxygen levels between 3-5 mg/L, but this level is sub-optimal and may reduce growth and survival. A DO of 3 mg/L is their lower oxygen limit for a 24-hour period. WDNR selected a minimum DO of 6 mg/L for the oxythermal criteria as a level that would sustain coldwater fish populations, consistent with the DO criteria of 6 mg/L for other coldwaters. Minnesota has used a DO concentration of 3 mg/L for their two-story fishery metric, but because this criteria is to be applied particularly at periods of peak stress and the thermal component of the criteria is based on the species' upper temperature limits, it was determined that a more protective oxygen level was needed to maintain a healthy population and prevent fish kills.
- The upper temperature limit for cisco is 73°F (22.8°C) (i.e., cisco will begin to die if exposed to temperatures above this limit for more than a few days). Their ideal range is ~39-63°F (~4-17°C), with an optimal temperature of ~48°F (9°C) (i.e. when given a choice, most cisco are found at this temperature if the DO is above 3 mg/L).
- The upper temperature limit for whitefish is ~66°F (~19°C). Their ideal range is ~39-52°F (~4-11°C), with an optimal temperature of ~39°F (~4°C).
- The upper temperature limit for lake trout is 57°F (14°C). Their ideal range is ~39-50°F (~4-10°C).

Setting criteria values

A lake's maximum acceptable temperature and acceptable DO are set based on the species that are expected to be present and reproducing within that lake. In the proposed rule language below, the temperatures shown in subdivision paragraphs a to d represent the maximum acceptable temperature at a DO of 6 mg/L for the species indicated. The thermal thresholds were selected to represent the point at which mortality begins to occur but most fish survive. In addition to appropriate temperature and DO characteristics, a two-story lake must have a minimum quantity of suitable habitat: a band of water of at least 1 meter that is at/below the indicated temperature and at/above the indicated DO. For example, a lake that has just an inch of water within the suitable ranges would not support coldwater species and would be considered impaired.

NR 102.04 (4) (am) *Oxythermal layer thickness for two-story fishery lakes.* 1. 'Criteria.' A two-story fishery lake shall maintain, during its period of summer stratification, an oxythermal layer of at least 1 meter in thickness that maintains both a dissolved oxygen concentration of at least 6 mg/L and a maximum temperature of the following:

a. For a two-story fishery lake with lake trout, 57° F or less.

b. For a two-story fishery lake with whitefish but not lake trout, 66° F or less.

c. For a two-story fishery lake with cisco but not whitefish or lake trout, or that the department manages for brook, brown, or rainbow trout, 73°F or less.

d. For a two-story fishery lake with multiple coldwater fish species, the applicable criterion under a. to c. is that for the lake's species requiring the lowest temperature.

Assessing attainment of the oxythermal layer criteria

To measure a lake's available volume of habitat, vertical temperature and DO profiles are taken in the deep part of the lake while the lake is stratified, at least monthly from July to September (earlier samples may be useful). Multiple profiles are typically needed to account for variability, both during the summer season and across years. A minimum of three years is recommended. To analyze, plots are made of both temperature vs. depth and DO vs. depth, and the vertical extent of the depth profile is determined at which the DO is 6 mg/L or above and the temperature is at the specified threshold or below. The depth of available habitat is then compared to the criterion. During any given year, if at any point the applicable criterion is not met, that year is an exceedance year. If more than one third of years sampled within the most recent 10-year period are exceedance years, the lake is not attaining the water quality criterion and would be listed as impaired on the section 303(d) list.

6. Phosphorus Assessment Methods

This rule creates a new section, ch. NR 102.07, which defines assessment procedures for the total phosphorus criteria found in ch. NR 102.06. It contains two major components: General assessment procedures, which reflect current protocols found in guidance, and a new component called the "combined approach" which applies a set of phosphorus response indicators to attainment determinations.

6.1 GENERAL PHOSPHORUS ASSESSMENT

The phosphorus criteria established in 2010 contained a numeric threshold but did not contain several other pieces of information that are critical to interpreting how to assess against that threshold. The information contained in this rule package provides the detail needed to apply clear assessment determinations.

The information in ch. NR 102.07(1), General assessment, contains data requirements for lakes and reservoirs and for flowing waters (rivers, streams, and impounded flowing waters). These specify where the criteria apply within a waterbody, the sampling period, the recommended number of samples for making an assessment determination, and the number of years over which samples may be applied for an assessment decision. Once samples are collected, it further describes the calculations necessary to compare the waterbody's phosphorus concentration to the TP criteria in ch. NR 102.06. Specifically, a lake's mean is compared to the criterion, and a flowing water's median is compared to the TP criterion. It describes the application of a confidence interval approach for determining whether more samples are necessary before making an attainment determination, referencing protocols found in proposed subchapter IV of ch. NR 102 (see section 2.1.2 of this document or WisCALM 2020 sections 4.4 to 4.6 for further detail). This is important in cases where a small number of samples are highly variable or very close to the criteria; additional samples can provide more certainty that a waterbody's true mean or median is above or below the criterion. These protocols reflect how phosphorus assessments have been conducted under the WisCALM guidance over time.

The proposed approach also requires that for flowing waters, the department calculate a weather-controlled median TP concentration to compare against the TP criterion. The weather-controlled concentration accounts for variability over time more accurately than a site's short-term sampling data. It is calculated using the department's Phosphorus Mixed Effects Regression (PhosMER) model, which uses the site's sampled TP data and the 30-year weather record to calculate the weather-controlled ambient concentration. The department plans to make the PhosMER model available on its website in a format that can be easily used by external parties. To date a similar tool is not yet available for lakes, but if one is developed it may be used for lake assessment determinations as well.

6.2 COMBINED APPROACH: U.S. EPA'S FOUR-PART PROCESS AND CONCEPTUAL MODEL

As part of WDNR's phosphorus assessment process, WDNR developed a suite of phosphorus response indicators. These are based on metrics that are most influenced by phosphorus, and can therefore serve as predictors of whether a waterbody is experiencing impacts due to phosphorus concentrations that are above the waterbody's phosphorus criterion.

The U.S. EPA developed a guidance document titled "Guiding Principles on an Optional Approach for Developing and Implementing a Numeric Nutrient Criterion that Integrates Causal and Response Parameters" ("Guiding Principles", USEPA 2013). Based on these principles, phosphorus response indicators should allow the state to have the capability to:

> "a) identify shifts in multiple biological assemblages (e.g., periphyton, benthic macroinvertebrates, fish) along a gradient of anthropogenic stress that can be tied to designated uses, and b) quantify the relationship between…phosphorus concentrations and measures of biological assemblage response."

The metrics selected should be sensitive to the stressor of interest (phosphorus) and should be relevant to protection of aquatic life designated uses. Measures of primary productivity and of algal assemblages are recommended as those most indicative of nutrient pollution. Higher trophic level indicators such as macroinvertebrates and fish may also be used as part of a suite of indicators, but should not be used as the sole indicator since they may not be as sensitive to phosphorus as lower-level indicators described previously. Dissolved oxygen or pH may serve as measures of ecosystem functioning.

WDNR also considered U.S. EPA's guidance titled "Using Stressor-Response Relationships to Derive Numeric Nutrient Criteria" ("Stressor-Response Guidance", USEPA, 2010) while developing phosphorus response indicators for Wisconsin. This guidance lays out a four-step process for deriving nutrient criteria and associated response indicators. The four steps are as follows (USEPA, 2010, p. ix-x):

> **1. Develop a conceptual model.** "…Conceptual models [are developed] representing known relationships between nitrogen (N) and phosphorus (P) concentrations, biological responses, and attainment of designated uses."
>
> **2. Assemble and explore data.** "Data are assembled and initial exploratory analyses are performed. Variables are selected during this step that represent different concepts shown on the conceptual model, including variables that represent N and P concentrations, variables that represent responses that can be directly linked with designated uses, and variables that can potentially confound estimates of stressor-response relationships."
>
> **3. Analyze data.** "…Stressor-response relationships are estimated between N and P concentrations and the selected response variables, and criteria are derived from these relationships."
>
> **4. Evaluate and document analysis.** "…The accuracy and precision of estimated stressor-response relationships are evaluated and the analyses documented."

This section covers each of those four steps. Step 1, the conceptual model on which the rest of the section is based, is shown below. Because Steps 2, 3, and 4 are waterbody and metric-specific, and are often highly iterative, they are described within various portions of this section under each waterbody type and phosphorus response metric. For each metric:

- Under Step 2, Assemble and Explore Data, we selected and refined datasets for which we had robust data and a representative number of sites, and for which data were collected using well-established methods. We focused, in part, on using metrics that were used in development of the state's 2010 phosphorus criteria (WI DNR, 2010). We also briefly summarize other metrics that were considered but not selected.
- Under Step 3, Analyze Data, we used a variety of statistical approaches to visualize and analyze the data. The statistical approaches used varied based on characteristics of each dataset.

- Under Step 4, we compared the various statistical analyses with one another to verify the soundness of the analysis and determine where to set criteria thresholds. We then documented these approaches and the justification for our determinations in this Technical Support Document to ensure transparency.

In summary, this section describes when the combined approach would be applied, the metrics selected as phosphorus response indicators and the justification for those selections, and briefly summarizes other metrics considered but not selected.

6.2.1 Conceptual model

WDNR developed the conceptual model shown in Figure 15 to depict commonly accepted pathways between nutrient inputs and cascading levels of responses in streams, rivers and lakes. The model includes three levels of response: primary, secondary, and tertiary, and how those responses impact Aquatic Life and Recreation Designated Uses. The U.S. EPA's "Stressor-Response Guidance" provides numerous references to publications documenting these effects (see Schindler 1974, Rosemond et al. 1993, Hill et al. 1995, Dodds and Welch 2000, Cross et al. 2006, Allen and Castillo 2007, Dodds 2007, Suplee et al. 2009). Wisconsin's conceptual diagram (Figure 15) is based primarily on the two diagrams shown in the U.S. EPA's "Stressor-Response Guidance", in EPA's Figure 2-1 for lakes and 2-2 for streams. However, we felt that a single and slightly more simplified model was accurate for representation of effects common to both lakes and streams/rivers. Wisconsin's model includes most of the same elements as depicted in the U.S. EPA's diagrams.

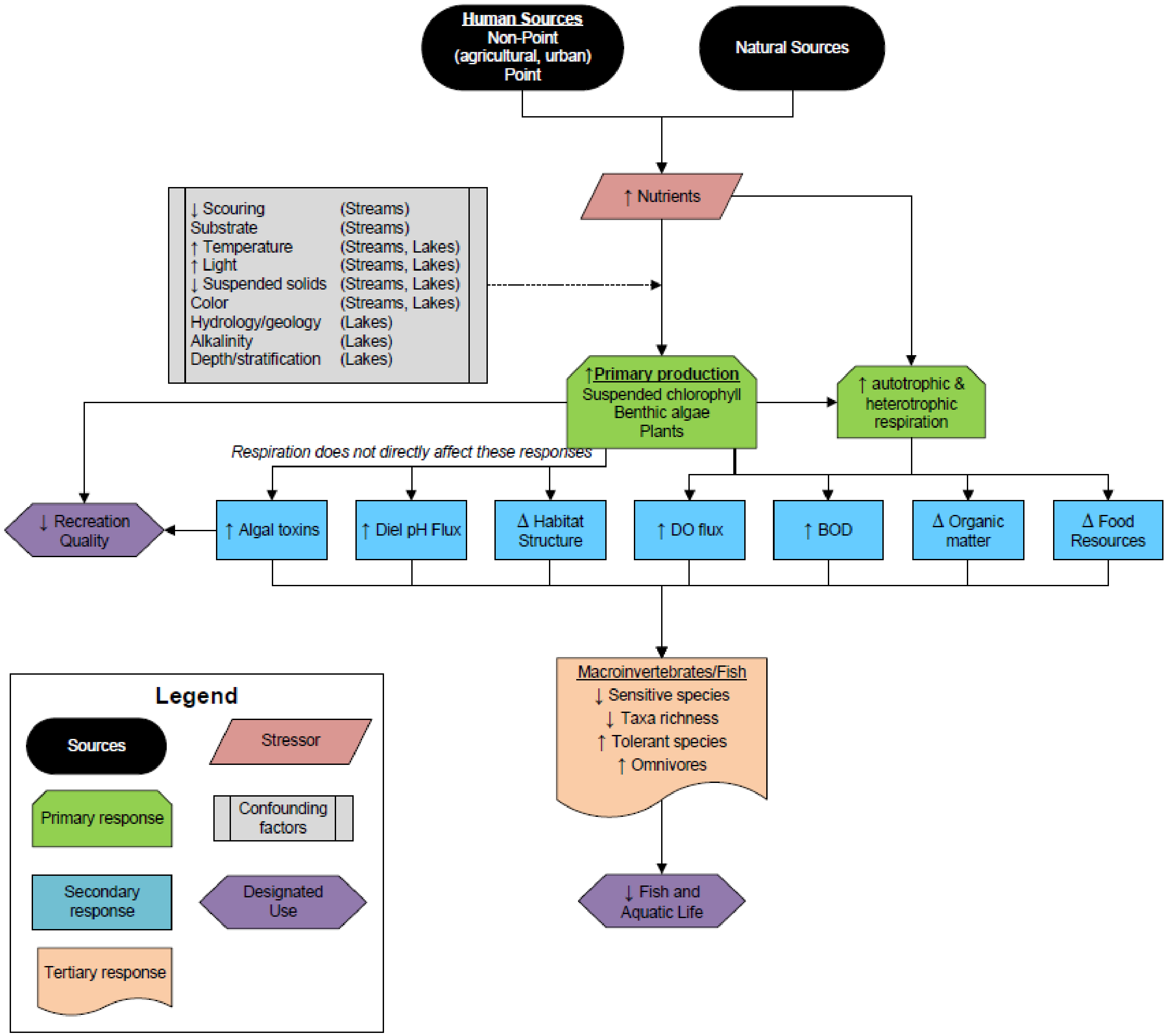
Primary response metrics
WDNR considered a variety of metrics depicted within this diagram for use as phosphorus response indicators, and concluded that the most immediate, direct and accurate measures of phosphorus response are the primary producers. The metrics selected to represent these primary response variables are benthic algal biomass and benthic diatom taxa for streams, suspended algae (chl *a*) for rivers, and aquatic plants and suspended algae (chl *a*) for lakes. Within the following sections of the section, there is discussion under each metric on how it responds to nutrient inputs and why it was selected as an appropriate indicator.

Secondary response metrics
Wisconsin already has numeric criteria representing two of the secondary response variables, dissolved oxygen concentration and pH. Because these criteria already exist, we did not include them directly as part of the phosphorus response indicators.

Tertiary response metrics
This rule package addresses tertiary response metrics as stand-alone narrative biocriteria to indicate overall community health, discussed in section 3 of this document. Biocriteria for streams and rivers are based on macroinvertebrates and fish. A tertiary response metric is not currently available for lakes, so the aquatic plant community is used as the most relevant and available assemblage-level biocriteria for lakes. Additional metrics may be added in the future as they become established.

Although we assessed tertiary response metrics for use as phosphorus response indicators, the relationship was not as direct as the primary producers, and therefore we did not include them as phosphorus response indicators at this time.

Figure 15. Conceptual model demonstrating primary, secondary, and tertiary responses to nutrient inputs in lakes, streams, and rivers. Based in part on conceptual models from the U.S. EPA 2010, Figures 2-1 and 2-2.



6.3 COMBINED APPROACH: APPLICABILITY

Phosphorus response indicators are meant to be used in conjunction with the state's phosphorus criteria, as a "Combined Approach", and would be codified as such. In the combined approach, if a waterbody exceeds its applicable phosphorus criterion, but within a prescribed range, then WDNR would monitor and analyze whether the waterbody is attaining its phosphorus response indicators before making a decision to list as impaired. If all phosphorus response indicators are attaining the established thresholds, the waterbody would not be listed as impaired for phosphorus. If any one phosphorus response indicator is not attained, the waterbody would be listed as impaired.

6.3.1 Range for applying phosphorus response indicators

Phosphorus response indicators are only used if a waterbody exceeds its phosphorus criterion, but within a certain range, as shown in the rule in ch. NR 102.07 Table B and Table 4 here. The upper bound of a waterbody's range for applying the combined approach is defined by WDNR's existing definition of an "overwhelming exceedance" of phosphorus for each waterbody type (WisCALM 2020). If a waterbody has an overwhelming exceedance of phosphorus, it will be listed as impaired without assessing the phosphorus response indicators. However, if the waterbody's concentration lies within the range between the criterion and its overwhelming exceedance threshold, phosphorus response indicators will then be examined to determine whether the waterbody should be listed as impaired.

The definition of an overwhelming exceedance is as follows:

- Streams/rivers: the lower limit of the 80% confidence interval around the waterbody's median TP concentration exceeds the criterion by two times or more.
- Lakes: the lower limit of the 80% confidence interval around the lake's mean TP concentration exceeds the criterion by 1.5 times or more.

Therefore, for streams/rivers the combined approach is used when a stream or river's concentration exceeds the criterion but by less than twice the criterion. For lakes the combined approach is used when the lake's concentration exceeds the criterion but by less than 1.5 times the criterion. Streams/rivers have a wider bioconfirmation range than lakes because of their wider natural variability in phosphorus concentrations.

The department will apply a confidence interval around the weather-controlled ambient phosphorus concentration in making these determinations.

Table 4. Range for applying combined assessment for total phosphorus[1]

Waterbody Type	Total Phosphorus Criterion (ug/L)	Combined Approach Range[2] (ug/L ambient total phosphorus)
Stream or its Impounded Flowing Water	75	75 to <150
River or its Impounded Flowing Water	100	100 to <200
Unstratified Reservoirs, Unstratified Drainage or Seepage Lakes	40	40 to <60
Stratified Reservoirs, Stratified Drainage Lakes	30	30 to <45
Stratified Seepage Lakes	20	20 to <30
Two-Story Fishery Lakes	15	15 to <22.5

[1]To determine whether a waterbody falls into the combined approach range, compare the lower confidence limit of the waterbody's two-sided 80% confidence interval around the mean (for lakes/rivers) or median (for rivers/streams) total phosphorus concentration to the ranges in the table.
[2]For streams and rivers the combined criteria range is between the applicable total phosphorus criterion and two times that criterion. For lakes, the range is between the applicable total phosphorus criterion and 1.5 times that criterion. If a waterbody has an approved site-specific phosphorus criteria, the combined criteria range for that waterbody shall be calculated using these multiplication factors.

6.4 LAKE/RESERVOIR PHOSPHORUS RESPONSE INDICATORS

Two main types of phosphorus response indicators are included in this rule package for lakes and reservoirs that are 5 acres or greater: algae (measured as suspended chlorophyll *a* concentration) and aquatic plants (macrophytes, expressed as the frequency of occurrence of macroscopic plants and algae). Additionally, for two-story fishery lakes, the oxythermal criteria apply as a phosphorus response indicator. Biological assessment based on lake water algal concentrations has been performed for years, whereas the macrophyte-based indicator is new to this rule package.

6.4.1 Suspended chlorophyll *a*

The chlorophyll *a* criteria for recreation and aquatic life described in detail in section 4 are also applied as phosphorus response indicators for lakes and reservors. Specifically, they are:

Chlorophyll *a* concentration (aquatic life criteria):
a. Mean suspended chlorophyll *a* concentrations in lakes and reservoirs other than stratified two-story fishery lakes shall not exceed 27 ug/L.
b. Mean suspended chlorophyll *a* concentrations in stratified two-story fishery lakes shall not exceed 10 ug/L.

Frequency of moderate algal levels (recreation criteria): A moderate algae level is defined as a chlorophyll *a* concentration of 20 ug/L or greater. Lakes, reservoirs, and impounded flowing waters shall not exceed the frequency of moderate algae levels specified in the table below during the summer sampling period.

Table 5. Recreational use criteria for frequency of moderate algae levels.

<table>
<tr><th>Waterbody Type[1]</th><th>Subcategory</th><th>Criteria for frequency of moderate algae levels</th></tr>
<tr><td rowspan="3">Lakes,
Reservoirs,
Impounded Flowing Waters
(includes cold and warm)</td><td>Impounded flowing water,
Unstratified drainage,
Unstratified seepage</td><td>Does not exceed 20 ug/L chlorophyll a for more than 30% of days during the summer sampling period[2]</td></tr>
<tr><td>Stratified drainage,
Stratified seepage</td><td rowspan="2">Does not exceed 20 ug/L chlorophyll a for more than 5% of days during the summer sampling period[2]</td></tr>
<tr><td>Stratified two-story fishery</td></tr>
</table>

[1] Terms used for waterbody types and subcategories are defined in s. NR 102.03. These criteria do not apply to streams or rivers.

[2] Summer sampling period is July 15 to September 15.

6.4.2 Aquatic Plants

Aquatic plants are sensitive to nutrient enrichment, and species-specific differences in tolerance to enrichment may be used to detect impairment in natural lakes. Thus, the composition of aquatic plant communities in many cases will show impairment prior to algal indicators. Aquatic plants play stabilizing roles in lake ecosystems, supporting clear-water conditions via a positive influence on settling rates, nutrient burial and uptake. Some lakes that are enriched with nutrients will not show evidence of impairment in their free-water dissolved phosphorus or chlorophyll *a* concentrations. However, as a lake begins to become enriched, plant community composition will shift toward more tolerant species adapted to enriched conditions. Therefore, we developed an assessment method relating aquatic plant abundance and tolerance to total phosphorus (Macrophyte Assessment of Condition for Phosphorus, or MAC-P). We employed the Macrophyte Assessment of Condition (MAC) method outlined in Mikulyuk et al. (2017), but we used water column total phosphorus as the disturbance measure rather than the integrated multimetric index of disturbance employed by the general assessment method. We grouped species into two clusters that differed in the estimated upper limit of their tolerance to total phosphorus. We split lakes into four groups by region and lake type and related the abundance of each tolerance cluster to observed phosphorus levels. We then determined thresholds that can be used to distinguish lakes along the enrichment gradient (Table 6). The phosphorus response indicators proposed here are based on data drawn from plant point intercept surveys conducted on 542 lakes sampled from 2005 to 2012 (Hauxwell et al. 2010, Mikulyuk et al. 2010). Details of the procedure are outlined below.

Table 6. Lake aquatic plant community phosphorus response indicator.

Subcategory: Lake Type[1]	Macrophyte Assessment of Condition for Phosphorus (MAC-P) attains if:
Northern Seepage	Phosphorus Tolerant ≤ 44.3%
Northern Drainage	Phosphorus Sensitive > 51%
Southern Seepage	Phosphorus Sensitive > 26%
Southern Drainage	Phosphorus Sensitive > 42%

[1] Northern lakes are those north of 44.84707° N latitude, and southern lakes are those south of that latitude. Seepage and drainage lakes follow the definitions in s. NR 102.03 (6h) and (1o). Seepage lakes include both stratified and unstratified seepage lakes, and drainage lakes include both stratified and unstratified drainage lakes. Plant phosphorus response indicators have not been established for Great Lakes and lakes less than 5 acres in surface area.

Phosphorus Response Thresholds

To develop plant-based phosphorus response indicators, we followed the general process described in Mikulyuk et al., 2017. Here we describe the process in five steps:

1) Determine the upper tolerance limit of each aquatic plant species to total phosphorus concentrations in the water column
2) Categorize species into one of two groups that vary in their sensitivity to phosphorus
3) Calculate how widespread each of the two plant groups (tolerant, sensitive) is in the lake
4) Split lakes into regional lake types to account for natural variation
5) For each lake type, define thresholds in the coverage of plant tolerance groups to split lakes into groups with similar total phosphorus concentrations

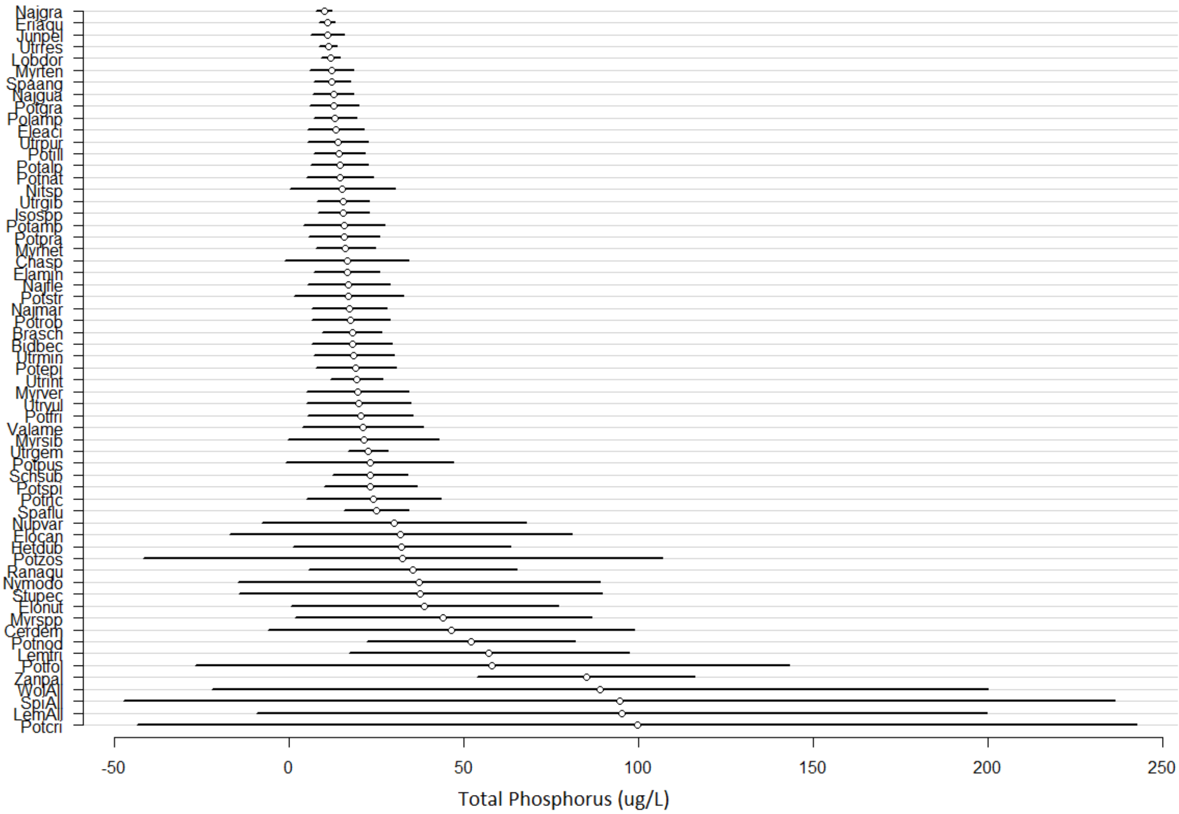
Plant Tolerance to Phosphorus (Step 1)

Here, we assume that a plant will be most commonly found in lakes that provide optimal conditions and more rarely found in lakes where it is physiologically stressed. We explored patterns in total phosphorus and species abundance in 592 Wisconsin Lakes. Phosphorus was expressed as the mean phosphorus concentration (ug/L) in lakes with at least 3 measurements occurring from May 1 to September 1 taken at most 5 years before or after the macrophyte survey. Mean yearly concentrations were averaged when they existed for multiple years.

We examined species-specific patterns in tolerance to phosphorus enrichment to ultimately link species abundance with phosphorus impairment. We represented species abundance as the percent frequency of occurrence observed in the littoral zone estimated using point-intercept aquatic plant surveys. To link species abundance and phosphorus enrichment, we estimated the optimum phosphorus concentration by species using an abundance-weighted average, where higher abundance for a given species indicates more suitable phosphorus conditions. We then estimated the phosphorus tolerance range, essentially the standard deviation of abundance-weighted phosphorus levels. The abundance weighting step means a species' tolerance range will be wider if it tends to have abundant populations in lakes far from the optimum, and more narrow if abundant populations only occur at close to the species' optimum level of total phosphorus. We found that species vary in their tolerance to total water column phosphorus concentrations: some species do not occur at high phosphorus concentrations whereas others are abundant across a wide range of phosphorus conditions (Figure 16).

Figure 16. Abundance-weighted average optima (open circle) and range (bars, ± 1 standard deviation) of phosphorus concentrations defining the distribution of aquatic plant species. Phosphorus concentrations (µg/L)

are on the x-axis and aquatic plant species are listed on the y-axis with the first three letters of the genus and then species names. For example, Najgra is *Najas gracillima*.



Phosphorus Tolerance Groups (Step 2)

After we determined the upper tolerance limit for each species, we used a statistical technique to group species with similar upper limits together (finite Gaussian mixture models, Fraley and Raftery, 2002). The best model divided species into two groups that are either sensitive or tolerant to phosphorus. There are morphological patterns evident across groups: phosphorus-tolerant species are generally tall species with finely-dissected or floating leaves that are less sensitive to light limitation and adapted to living in nutrient-rich waters, whereas phosphorus-sensitive species tend to be short and compact or have wide, un-dissected leaves.

Frequency of Phosphorus Tolerance Groups (Step 3)

The plant "point intercept" sampling method uses a rake to collect plants at points on a lakewide grid scaled to produce more points on lakes with larger littoral zones and more complicated shorelines (Mikulyuk 2010). For any given lake, this sampling results in a list of plant species that were found at each point on the grid. To characterize how widespread a given plant is, we can count the number of points where the species was found and divide by the number of sampled points. This is called the frequency of occurrence. To focus on the composition of aquatic macrophyte communities in only the

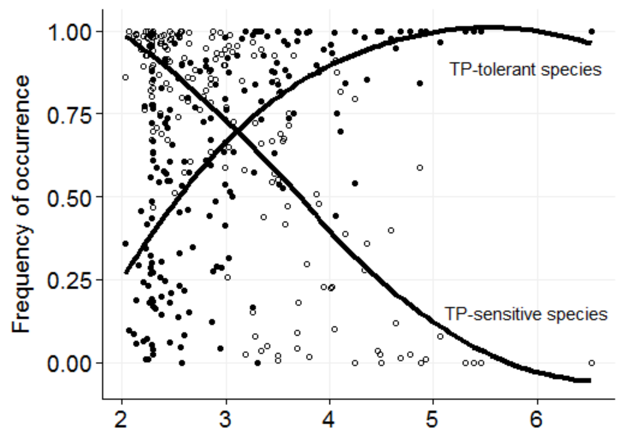


Figure 17. Abundance of TP-tolerant and TP-sensitive species along a phosphorus gradient.

vegetated areas of the lake and account for variation in the size of the profundal zone (area at depths where light cannot penetrate) across lakes, we counted species occurrence only at points that had vegetation. We therefore expressed species abundance as vegetated frequency of occurrence. We estimated this value for each tolerance group using the number of points at which either a tolerant or sensitive species was observed out of the total number of vegetated points. For example, if 50 of 100 points have aquatic plants and 30 of the 50 vegetated points have tolerant plants, then the tolerant vegetated frequency of occurrence is 60%. Note that because we required at least 15 observations to determine a species' tolerance range, some plant species were not assigned a tolerance group and were removed from this analysis. That means that points with only rare species present would not count toward the denominator number of vegetated points.

Natural Lake Groups (Step 4)

There is a strong north-south gradient in geology, climate, and land use that naturally affect plant community composition. Based on a previous analysis of multi-scale patterns in aquatic plant community composition, we divided northern lakes from southern lakes at 44.84707° N latitude (Mikulyuk 2011). Seepage lakes (lakes with no outlets) tend to have different characteristics than drainage lakes (lakes with at least one perennial stream outlet), so we also divided lakes based on this hydrological characteristic. Reservoirs are included with drainage lakes.

Defining Thresholds (Step 5)

We used a conditional inference framework to partition lakes with similar phosphorus levels into internally-consistent groups using macrophyte abundance data. We created a set of rules/thresholds for northern seepage lakes, northern drainage lakes, southern seepage lakes, and southern drainage lakes (Figure 18). These were then translated into the thresholds shown in the phosphorus response indicator table, Table 6 at the beginning of this section.

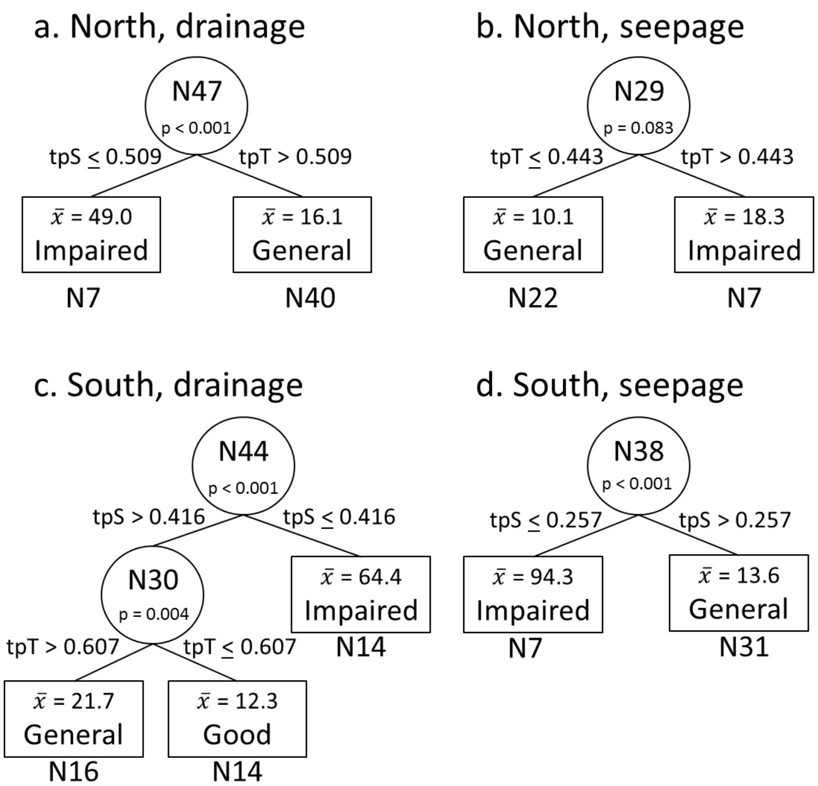


Figure 18. Conditional inference trees relating vegetated frequency of occurrence by TP-tolerance cluster to lake Total Phosphorus. Sample size indicated following N, p-values are printed in each node, with mean TP concentration and TP-condition category labels in leaves. Threshold values of TP-Sensitive (tpS) or TP-Tolerant (tpT) vegetated frequency of occurrence are printed at each split.

6.4.3 Oxythermal layer criteria

For two-story fishery lakes, the oxythermal layer thickness criteria specified in s. NR 102.04 (4) (am) also applies as a phosphorus response indicator. Elevated phosphorus can lead to oxygen depletion in lakes and reduce the habitat necessary for coldwater fish. Although phosphorus may not be the only factor affecting oxythermal habitat, if the oxythermal habitat requirement is not met in a waterbody with elevated TP levels, it is inappropriate to determine that the waterbody is not experiencing stress due to phosphorus (and not list it as impaired for TP) unless further studies indicate otherwise.

6.5 RIVER PHOSPHORUS RESPONSE INDICATORS

6.5.1 Suspended chlorophyll *a*

For rivers, suspended chlorophyll *a* is established as the only statewide phosphorus response indicator at this time. Algal productivity is assessed in rivers using the same metric as for shallow lakes and reservoirs and impounded flowing waters: a suspended chlorophyll *a* concentration of 20 ug/L may not be exceeded more than 30% of the summer sampling season (July 15-September 15). We conducted the following analysis to examine the application of this threshold to rivers.

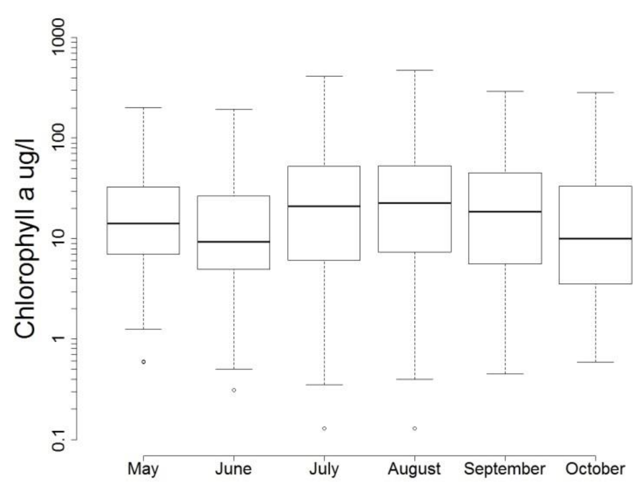
Wisconsin's water quality criterion for total phosphorus (TP) in nonwadeable rivers is 100 ug/L. The impacts of phosphorus in river systems vary depending on a number of factors including physical features, light availability to the water column and benthos, and phosphorus uptake pathways (i.e. benthic algae and macrophytes or phytoplankton). In river and impoundment ecosystems a common response to increased phosphorus is increased phytoplankton in the water column (measured as chlorophyll *a*), potentially reaching moderate algae levels. Suspended (sestonic) chlorophyll *a* was one of the primary indicators used in development of Wisconsin's total phosphorus criteria in 2010, which noted that nonwadeable rivers exhibited a strong correlation between total phosphorus and the amount of suspended algae as measured as chlorophyll *a* (WI DNR, 2010).

Determination of criteria thresholds

We used two datasets from nonwadeable river monitoring programs to evaluate the TP-chlorophyll *a* relationship and determine a threshold that confirms a phosphorus response. We used data from the nonwadeable river Long Term Trends (LTT) monitoring program which monitors 43 river sites across the State. Each site is sampled monthly (~2/3 of sites) or quarterly (~1/3 sites) over multiple years (http://watermonitoring.uwex.edu/pdf/level2/symposiumreferenceLTTAnnualReport2006.pdf). The LTT Rivers dataset spans rivers across gradients of size, geography, ecoregion, land use and human modifications representing the broad range of conditions seen in nonwadeable rivers across the state. We added to this dataset by including data from the *Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin* report by Robertson et al. (2008). This project sampled river sites over a 6 month period in 2003 from May through October. There was some overlap from the two datasets so we combined data that were from the same or proximal locations into one site for analysis.

The first step in the analysis was to determine the appropriate index period for chlorophyll *a* in nonwadeable rivers. Chlorophyll *a* concentrations vary seasonally due to factors such as water temperature, light and nutrient concentrations. Two options already in use by WDNR for assessments include sampling TP in wadeable streams (monthly, May to October) and sampling TP and chlorophyll *a* in lakes (monthly, July-September). Using only sites that had multiple years of monthly data (n=31) we compared chlorophyll *a* values across all months and found that in nonwadeable rivers, on average, chlorophyll *a* concentrations were highest in July, August and September (Figure 19). We tested the two possible index periods to determine if there were any differences among the chlorophyll *a* values in each month over the two different index periods. For the July-September index period, there were no significant differences in chlorophyll *a* among months (ANOVA, p=0.33). However, there were significant differences in chlorophyll *a* among months in the May-October index period (ANOVA, p<0.001). Based on these findings, we decided to use July, August and September as the index period for assessing chlorophyll *a* in nonwadeable rivers. This represents both the most sensitive time period for algal response and the typical swimming period for protection of recreational uses. In addition, because there were no differences in the distribution of chlorophyll *a* among the July-September index period we were able to include sites that had only quarterly sampling events in our dataset.

Figure 19. Chlorophyll *a* concentrations from 2003-2013 among all months considered to determine the appropriate index period



Recreational uses of nonwadeable rivers are similar to shallow lakes, including boating, fishing, and swimming. Therefore, the proposed definition of moderate algae levels in rivers is the same as in shallow lakes: 20 µg/L chlorophyll *a*. To determine the acceptable frequency of moderate algae conditions in nonwadeable rivers, we plotted the estimated frequency of chlorophyll *a* > 20 µg/L during July-September against the median growing season (May-Oct) TP (Figure 20). For this analysis, we used data from all nonwadeable rivers in Wisconsin with at least 6 chlorophyll *a* and TP samples (n=49).

We used a Receiver Operating Characteristics (ROC) analysis to identify the frequency of moderate algae levels that best separates rivers that meet and exceed the TP criterion (Figure 21). This analysis plots the sensitivity (correct positive) and specificity (correct negative) rates across a range of potential thresholds. The frequency of moderate algae that best separates rivers that meet and exceed the TP criterion is in the range of 25-50%. Because the independently-determined shallow lake threshold of 30% is in this range, and for consistency, the proposed chlorophyll *a* criterion in nonwadeable rivers is 20 µg/L, to be exceeded no more than 30% of the time in July-September.

Most of the rivers that exceed the TP criterion but not the chlorophyll *a* criterion are in the Driftless Area and have high turbidity, which limits algal growth. The macroinvertebrate IBI may be a more appropriate TP response indicator in these rivers. All of the sites that exceed the chlorophyll *a* criterion but not the TP criterion are on the Wisconsin or Fox Rivers, and are downstream of impoundments. TMDLs for TP in these systems will consider the hydrologic conditions that lead to high algal productivity.

Figure 20. River frequency of moderate algae levels versus growing season median total phosphorus concentration (49 Wisconsin rivers).

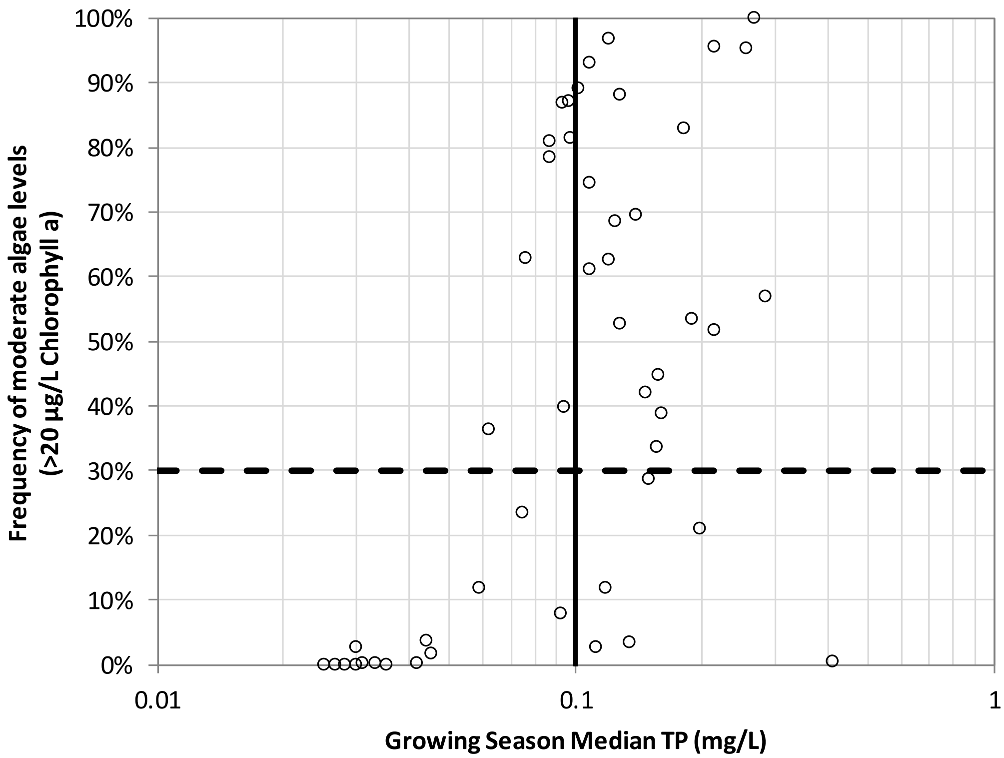
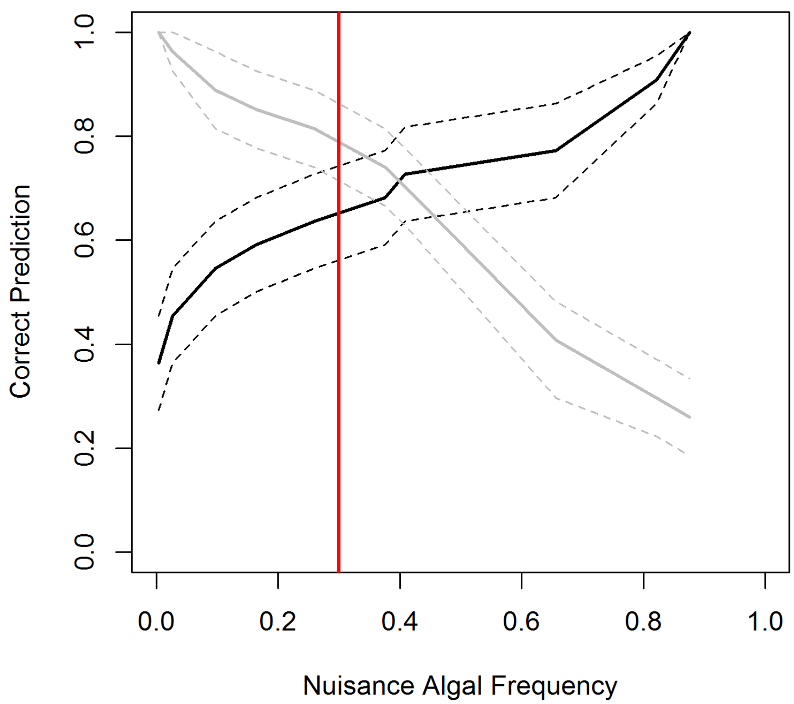


Figure 21. Plots of sensitivity (grey line) and specificity (black line) for frequency of moderate algae levels to correctly classify a river site as being above or below the TP criterion. Vertical red line indicates proposed river threshold for frequency of moderate algae levels.



6.5.2 Other metrics not selected

The following primary productivity metrics were considered for development of river phosphorus response indicators but were not selected.

- **Macroinvertebrates**. Macroinvertebrates can be a useful indicator in rivers because some rivers are too turbid to allow enough light penetration for algal growth, even if enough phosphorus is available that it would otherwise cause high algal concentrations. Macroinvertebrate communities are strongly connected to the river benthos and are influenced by increased benthic autotrophic and heterotrophic production through changes in oxygen dynamics and food and habitat quality, and for this reason could be a useful secondary indicator. The River Macroinvertebrate Index of Biotic Integrity (MIBI) had a relatively strong correlation with phosphorus (R-squared 0.31; see Weigel and Dimick, 2011 for calculations of metrics). However, for simplicity of focusing the phosphorus response indicators on primary production, we do not propose to include macroinvertebrates at this time. Nonetheless, macroinvertebrates may be a useful additional indicator in certain river systems.
- **Benthic chlorophyll *a*.** Benthic chlorophyll *a* is difficult to systematically collect in rivers because adequate substrate is usually lacking to collect a sample. Sestonic chlorophyll *a* is a better river indicator.
- **Diatoms – DNI and DBI.** The Diatom Nutrient Index (DNI) and Diatom Biotic Index (DBI) were developed for wadeable streams and are not appropriate to apply to river sites.
- **Secchi depth.** A Secchi tube clarity reading is not required for purposes of biocriteria or the combined approach for phosphorus. Since a Secchi depth reading frequently reflects suspended sediment as well as algae growth, a chlorophyll *a* sample is a more direct measure of biological response to phosphorus.

However, a Secchi tube may be included as part of a regular sampling regimen if established by monitoring protocols to provide additional context.

- **Algal toxins.** While production of algal toxins can be a result of high TP concentrations, algal toxins are not recommended as a primary phosphorus response indicator. High algal toxins are more likely to be a problem in rivers than in streams. However, at the current time, protocols for assessing algal toxins are insufficient. An algal toxin sample may be collected and analyzed in a river if a problem is suspected, and the analysis may be used as supplementary evidence of a problem.

6.6 IMPOUNDMENT PHOSPHORUS RESPONSE INDICATORS

6.6.1 Suspended chlorophyll *a*

For impounded flowing waters, suspended chlorophyll *a* is established as the only statewide phosphorus response indicator. Algal productivity is assessed in impoundments using the same metric as for shallow lakes and reservoirs and for rivers: a suspended chlorophyll *a* concentration of 20 ug/L may not be exceeded more than 30% of the summer sampling season (July 15-September 15). This criterion is applied regardless of whether the impoundment is on a river or a wadeable stream.

6.6.2 Other metrics not selected

Other potential phosphorus response indicators, including benthic algal biomass, benthic diatom community structure, lake aquatic plant index, or the macroinvertebrate IBI, are generally not applicable to impounded flowing waters for two main reasons. First, the datasets used to develop these criteria did not include impounded flowing waters. Second, several characteristics of impounded flowing waters, including depth, velocity, and substrate, differ from natural lakes and free-flowing rivers enough to influence habitat conditions for plant and animal communities. However, these or other metrics may be required by the department on a case-by-case basis depending on a given site's characteristics.

6.7 STREAM PHOSPHORUS RESPONSE INDICATORS

6.7.1 Nutrient Impacts Dataset

The department used the Nutrient Impacts Dataset (Version 2) for development of stream phosphorus response indicators. To determine which stream metrics have the strongest correlation to TP concentrations, and thus which would best represent the variables in the conceptual model, WDNR assembled existing data from three different studies spanning ten years. The 197 stream sites that were used for this analysis included 171 sites from the 2001-03 wadeable stream nutrient impacts study (Robertson et al. 2006), 8 sites from WDNR's 2007-09 watershed rotation study, and 18 sites from WDNR's 2011 high N:P ratio study. The sites were selected to span the range of nutrient conditions and to minimize the correlation between total phosphorus and total nitrogen. The dataset included a variety of metrics for fish, macroinvertebrates, and diatoms, and includes sites from each Natural Community and Ecoregion. From this dataset the department determined that benthic algae had the strongest correlation with TP in wadeable streams. The dataset was further used in development of the Diatom Phosphorus Index described in this section.

6.7.2 Benthic algal biomass & diatom taxa

For streams, primary productivity can be measured in one or both of the following ways. To maximize efficiency for making assessment decisions, the "viewing bucket" method for algal biomass is recommended as the first step in assessing primary productivity. If these results are conclusive, as described below, no further analysis is required. If the results are inconclusive (mid-range scores), further analysis of the diatom community is required to determine whether the stream is exhibiting a TP response.

a. Viewing Bucket for algal biomass
A visual assessment of benthic algal biomass in streams using a quantifiable system such as a viewing bucket is an efficient and appropriate screening tool to determine whether a site clearly is, or is not, exhibiting a nutrient response. High TP can be expected to result in greater biomass and coverage of benthic algae in streams. The viewing bucket method is included in the *U.S. EPA's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (Barbour et al. 1999) and is used in several states' monitoring programs.

The method will be employed during evaluation of habitat assessment transects. Benthic algal biomass will be observed and characterized on a grid with a minimum of 25 points with the viewing bucket (Figure 22). This will be done once on each of the twelve habitat transects (WDNR 2002) for a reach, staggered across the stream from left to right. Scores from each transect will then be averaged for the reach.

The assessment should be conducted during the growing season (July, Aug, or Sept) during baseflow conditions, with the first viewing bucket assessment in July or August, and second (if needed) in August or September. Because scouring during stream spate events may reduce algal biomass, sampling should be avoided within 14 to 21 days of a storm event.

Figure 22. An example viewing bucket from Rhode Island Dept. of Environmental Management. Photograph by A. Patterson.

Thresholds for algal biomass as evaluated with the viewing bucket method reflect the expectation that higher TP levels will lead to higher algal biomass. The viewing bucket scoring scale is from 0 (low biomass) to 3 (high biomass) (Table 7). If the average algal biomass score for the reach is less than 1, the stream is not impaired by TP and there is no need for further primary production assessment. If the algal biomass score is greater than 2, the stream is impaired by TP and no further assessment is necessary. If the algal biomass score is between 1 and 2, further primary production assessment via the Diatom Phosphorus Index (DPI) is needed.

Table 7. Stream benthic algal biomass phosphorus response indicator using viewing bucket method.

Benthic algal biomass, viewing bucket score (0-3)	Attainment decision	
	Aquatic Life Use	**Recreation Use**
< 1	Attained[1]	Attained
1 - 2	Inconclusive; assess benthic diatoms using DPI	
> 2	Not attained	Not attained

[1] If the mean score is <1 but 20% or more of individual transect points score a 3, a benthic diatom assessment under par. (b) is required to make an attainment determination.

The viewing bucket method can also be used to assess whether a stream is attaining its recreation use, as recreation is also impacted by algal growth. A stream's recreation use is considered attained if the viewing bucket score is at 2 or below.

b. Diatom Phosphorus Index (DPI)

Diatoms are a form of algae with a silicate shell with many species that tend to be found on stream beds or clinging as a brown substance to filamentous algae, such as Cladophora. They are found in both freshwater and marine waters and in many environments play a very substantial role in primary productivity within the system. Analysis of diatoms has been used for water quality analysis around the world. Various species have been identified as tolerant or sensitive to various stressors, including nutrients.

In development of phosphorus criteria for wadeable streams, WDNR used three indices to evaluate diatom community responses to phosphorus: the Diatom Nutrient Index (DNI), the Diatom Siltation Index (DSI), and the Diatom Biotic Index (DBI) (Robertson et al. 2006). Because these indices are primarily based on literature-derived tolerance values that are not specific to phosphorus, we decided to develop a new method that is specific to phosphorus and calibrated to Wisconsin diatom data, herein referred to as the Diatom Phosphorus Index (DPI).

The DPI is based on a statistical method called Weighted Averaging (WA; ter Braak and van Dam 1989). This method can be used to determine whether the diatom community at an assessment site resembles the community that is typically found at sites meeting the stream TP criterion. The TP criterion is based on breakpoints in the relationships between TP and diatom (and other biological) metrics, and as such represents the level of TP where the biological community changes the most.

WA estimates species-specific environmental preferences (optima) as the average value of an environmental variable (in this case, TP) where a species occurs, weighted by its relative abundance. The DPI at a site is then estimated as the weighted average of the TP optima of all the species present at that site. WA was developed to infer paleo-limnological characteristics such as pH, temperature, and TP (reviewed in Juggins and Birks 2012), and has also been used to develop a stream diatom nutrient index in New Jersey (Ponader 2007).

A WA model was developed from the Nutrient Impacts (Version 2) Dataset described above. Diatom and nutrient samples were collected in 2001-03 and 2011 using methods described in Robertson et al. (2006). Diatom samples were collected in September, and nutrient samples were collected monthly from May-Oct. Models using various subsets of nutrient samples during and prior to September were evaluated to determine whether they were better predictors of diatom community structure than the entire growing season, but the median of all six monthly samples was the best predictor. Only taxa with at least five occurrences (n=156) were used in the model development.

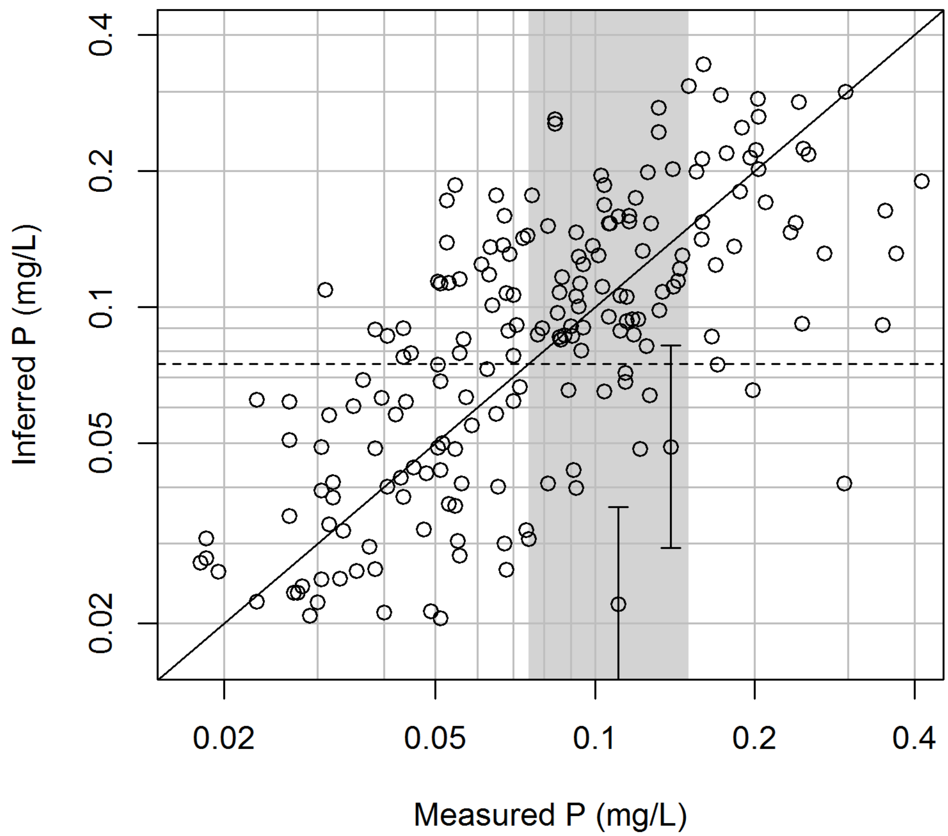
The WA model was fit using the WA function in the rioja package (Juggins 2014) in R. Prediction errors were estimated by leave-one-out cross-validation. The cross-validated r^2 is 0.49, which means that TP explains about half of the variation in diatom community structure among sites (Figure 23). The root mean square error of prediction (RMSEP) is 62%, which means that the average DPI differs from the measured TP by 62%. The residual variation in this relationship probably reflects sampling error in both TP and diatoms. The DPI may actually be a more accurate reflection of prevailing phosphorus conditions than direct stream TP measurements.

For purposes of assessing attainment of the diatom phosphorus response indicators, the department would not list a waterbody as impaired if it is 90% confident that the diatom community is not impaired. A bootstrapping procedure[3] was used to estimate confidence intervals around DPI values. If the upper 80% confidence limit of DPI is < 75 µg/L, we would be 90% confident that the diatom community is not impaired. Among the 68 sites in the model dataset where biological confirmation would be relevant (measured TP is 75-150 µg/L), only two would be considered not impaired through the perspective of the diatom community.

For assessment purposes, the DPI should be used only in conjunction with TP, not as a stand-alone assessment metric. It has not been shown to be sensitive to a broader range of environmental stressors than phosphorus. However, high algal viewing bucket scores may be used to list a water as impaired regardless of TP concentrations.

[3] In rioja, the predict function with sse=TRUE estimates standard errors for each site (v1), which reflect how much the inferred P varies across the bootstrapped samples.

Figure 23. Measured vs. diatom-inferred TP concentration from Weighted Average (WA) model (R2 = 0.49). Note log scales on both axes. Gray area is TP range where biological confirmation may be used. Error bars are 80% confidence intervals on two example points.



6.7.3 Other metrics not selected

For streams, we determined that primary production metrics were the most appropriate as phosphorus response indicators, and upper-level indicators did not add clear value to assessment of phosphorus response. We considered both macroinvertebrate and fish metrics, as described below, but determined that the relationships between these metrics and phosphorus, as assessed using currently available data, were not strong enough to include as response indicators.

The following primary productivity metrics were considered for development of stream phosphorus response indicators but were not selected.

- **Benthic chlorophyll *a*.** Benthic chlorophyll *a* is a useful metric in streams; however, physical sampling of chlorophyll *a* is highly variable in streams as growth is patchy and strongly influenced by substrate type and substrate selected for sampling (i.e. selection bias) making the development of a clear relationship with TP and an appropriate threshold difficult. Additionally, the viewing bucket method incorporates benthic algae but over a larger portion of the streambed. Though this metric will not be required in code at this time, staff are able to collect benthic algae via a rock scrape for chlorophyll *a* analysis, to be used as supplemental information and to help build WDNR's dataset on benthic chlorophyll *a*. Obtaining additional data will help the department refine benthic chlorophyll *a* thresholds in the future.

- **Sestonic chlorophyll *a*.** Streams do not typically have high sestonic (suspended) chlorophyll *a* levels, so a grab sample of sestonic chlorophyll *a* is not needed for stream sites. Sestonic chlorophyll *a* is a more appropriate indicator for rivers.
- **Algal toxins**. While production of algal toxins can be a result of high TP concentrations, algal toxins are not recommended as a primary phosphorus response indicator. High algal toxins are very rarely a problem in streams. At the current time, protocols for assessing algal toxins are insufficient. However, an algal toxin sample may be collected and analyzed in a stream if a problem is suspected, and the analysis may be used as supplementary evidence of a problem.
- **Diatom Nutrient Index (DNI) and Diatom Biotic Index (DBI).** The weighted average Diatom Phosphorus Index (DPI) was selected over the Diatom Nutrient Index (DNI) or Diatom Biotic Index (DBI) because it shows a stronger correlation with phosphorus.

Macroinvertebrate and Fish Metrics

To support the continued development of stream nutrient criteria, including phosphorus response indicators, WDNR conducted an extensive set of analyses on biotic responses to nutrients. This study is described in detail in a report titled "Evaluation of the relative effects of phosphorus and nitrogen on stream biological community structure" (Diebel 2015). One of the major conclusions of this study is that nitrogen and phosphorus have independent and statistically significant effects on the community structure of all taxonomic groups, but the strength of those effects is relatively weak compared to other environmental variables, except for the effect of P on diatoms, which is strong. In particular, both macroinvertebrate and fish communities are more strongly influenced by stream size, temperature, and conductivity than by phosphorus. These higher taxonomic groups are useful indicators of overall biological integrity in streams, but do not match the specificity of primary producers as a phosphorus response indicator.

6.8 IMPAIRED WATERS LISTING USING PHOSPHORUS RESPONSE INDICATORS

The department provided a data analysis to the External Stakeholder Committee in 2016, to provide information on the number of waterbodies that would be kept off of the section 303(d) impaired waters list using the combined approach to apply phosphorus response indicators. That analysis is summarized here. As discussed with the stakeholder committee, the percent of waterbodies that exceed the statewide P criteria but are not experiencing a biological response is small. This indicates that the statewide P criteria are set at a level that is not overly protective for most waterbodies. The following datasets contain a relatively small portion of the waterbodies in the state. As the phosphorus response indicators are applied more broadly, additional waterbodies are expected to be determined to be attaining these indicators.

Streams: There are 182 stream sites that have been evaluated for P for which diatom analysis has also been conducted. Of those 182 sites, 67 sites exceed the phosphorus criterion but are within the P range at which the combined approach can be applied. Six of these sites attained the diatom phosphorus response threshold and would therefore be removed from the impaired waters list for P or would not be listed for P when they otherwise would have been.

Rivers: There are 28 river sites that have been evaluated for P for which chlorophyll *a* data have also been assessed. Of these, 11 exceed the P criterion but are within the range at which the combined approach can be applied. Two of these attain the phosphorus response indicator for frequency of moderate algae levels, and would therefore be removed from the impaired waters list for P or would not be listed for P when they otherwise would have been.

Lakes: There are 161 lakes that have P data and also have data for the three main phosphorus response indicators: frequency of moderate algal levels (to protect recreation use), chlorophyll *a* concentration (to protect aquatic life use), and the plant phosphorus response tool (aquatic life). Of these 161 lakes, 28 exceed the P criterion but are within the P range at which the combined approach can be applied. Eight of those lakes attain all three phosphorus response indicators and would therefore be removed from the impaired waters list for P or would not be listed for P when they otherwise would have been.

7. Applying biologically-based metrics to site-specific criteria for phosphorus

7.1 STATEWIDE PHOSPHORUS CRITERIA AND THE NEED FOR SITE-SPECIFIC CRITERIA

Concurrent with this rule package (WY-23-13, referred to here as the assessments rule), a second rule package (WT-17-12) is underway to establish a process for deriving site-specific criteria for phosphorus for individual waterbodies when needed. Rule package WT-17-12 would create a new rule, ch. NR 119, to house this process. The SSC rule package cross-references the biologically-based metrics contained in the assessments rule that are discussed within this Technical Support Document. Therefore, a short discussion is included here regarding the interplay between the biological metrics in this rule and the proposed SSC rule[4].

Wisconsin promulgated its statewide phosphorus criteria in December 2010 following the publication of ch. NR 102, Wis. Adm. Code. In reviewing statewide data trends, the Department has concluded that the statewide phosphorus water quality criteria are appropriately protective in most cases. However, there may be some instances for specific waterbodies where the applicable statewide phosphorus criterion is more stringent than necessary to protect the designated uses of the waterbody in question. Alternatively, there may be some waterbodies, such as certain impounded flowing waters, that are not being adequately protected by the current phosphorus criteria. In such cases, federal and state law allow for development of site-specific criteria—criteria that are applicable only to a specific waterbody or waterbody segment, based on site-specific circumstances—which are more appropriate for individual waterbodies. After taking effect, an approved SSC becomes the applicable water quality standard for the approved waterbody or segment.

Authority for developing SSC for any substance is already contained in s. 281.15, Stats. The proposed SSC rule does not create additional authority; it establishes a process under which SSC development can be carried out. Establishment of this process will provide consistency and transparency, specifying the type of information needed to make an approvable demonstration that an SSC is appropriate for an individual waterbody.

[4] The SSC rule package does not require a separate Technical Support Document because it does not consitute a new water quality standard in and of itself; it sets a process for deriving criteria. Each individual SSC developed using the new process (or any other process) would still be approved separately by EPA, along with its own analysis.

7.2 UNDERLYING PRINCIPLE: PROTECTING DESIGNATED USES

Site-specific criteria must be set at levels that are protective of a waterbody's designated uses. In Wisconsin, the main uses associated with phosphorus are Recreation and Aquatic Life (which is further divided into several subcategories). The statewide phosphorus criteria were developed to be protective of both of these types of uses. Similarly, during development of any site-specific criteria, one of the critical goals is to select a criterion that maintains or improves protection of an individual waterbody's uses, based on the waterbody's specific ecological context and response to phosphorus. For example, some waterbodies may naturally be less sensitive to phosphorus, and can therefore assimilate more phosphorus than others without adverse impacts to their uses. Other waterbodies may be more sensitive to phosphorus and experience biological responses and use impairments at lower levels than usually expected. In general, it may be appropriate to derive a site-specific criterion for phosphorus in either of the following scenarios:

1) The statewide criterion is not stringent enough to protect a waterbody's designated uses. Despite the applicable statewide phosphorus criterion being met, the designated uses of a given water or waterbody segment are not attained.
   → **In this case, a *more stringent* SSC may be needed.**

2) The statewide criterion is more stringent than reasonably necessary to assure attainment of the designated uses for the waterbody in question and adjacent downstream waters (if applicable).
   → **In this case, a *less stringent* SSC may be appropriate.**

It is important to note the underlying premise that a criterion may be more or less stringent but equally protective of the designated uses. The stringency needed is based on the sensitivity of the waterbody in question. A less stringent criterion may be equally protective where, due to the specific chemistry, geology, or morphology of a site, the biological community of a waterbody exhibits less sensitivity or response to phosphorus than most waterbodies. This may include areas of the state where naturally high levels of phosphorus have always existed, due to the underlying geology, and the biology is adapted to those levels. It may also include sites that naturally have fewer species that are sensitive to high phosphorus levels. Conversely, some sites may need a more stringent phosphorus criteria because they are naturally more sensitive to phosphorus impacts.

It is also important to clarify that an SSC is a water quality standard to protect aquatic life, recreation, and other uses, rather than a compliance tool for permittees. Compliance tools for meeting phosphorus permit limits include water quality trading and adaptive management. If a permittee cannot comply with permit limits because it would cause economic hardship, an individual or multi-discharger phosphorus variance is available. A waterbody is only eligible for an SSC if an adjusted phosphorus criterion is appropriate based on the biological responses of the system.

7.3 USING BIOLOGICAL METRICS TO REPRESENT DESIGNATED USE ATTAINMENT

To determine whether a waterbody's designated uses are being met, certain biological metrics are used to indicate the ecosystem's response to phosphorus and whether uses are being impaired. The biological metrics are different for different waterbody types. Two types of biological metrics that are delineated in ch. NR 102 revisions that are described in this Technical Support Document are integral to SSC development:

1) **Phosphorus response indicators.** (proposed ch. NR 102.07) Phosphorus response indicators are based on biological metrics that are particularly responsive to phosphorus, such as algae (as

measured through chlorophyll *a*) and aquatic plants. They are used to determine the effects of phosphorus within a waterbody, including attainment of phosphorus criteria and designated uses.
2) **Biocriteria.** (proposed ch. NR 102 Subch. III) Biocriteria are based on an assessment of the overall health of key biological communities, such as fish, aquatic insects, and plants, which is used to determine support of aquatic life designated use subcategories.

The phosphorus response indicators and biocriteria for each waterbody type are found in proposed ch. NR 102.07 and ch. NR 102 subch. III, respectively. They are also detailed in sections 6 and 3 of this Technical Support Document. They are based on the following metrics:

- **Lakes/reservoirs:**
  - Phosphorus response indicators: suspended chlorophyll *a* (indicating algae growth) and aquatic plants (macrophytes), plus oxythermal habitat criteria for two-story fishery lakes
  - Biocriteria: aquatic plants
- **Streams:**
  - Phosphorus response indicators: benthic algal biomass and benthic diatom taxa (diatoms are a type of hard-bodied algae that grows on the substrate)
  - Biocriteria: aquatic insects (macroinvertebrates) and fish
- **Rivers:**
  - Phosphorus response indicator: suspended chlorophyll *a*
  - Biocriteria: aquatic insects and fish
- **Impoundments:**
  - Phosphorus response indicator: suspended chlorophyll *a*
  - Biocriteria: Not applicable (can be required case-by-case as determined by the department)

Additional indicators may also be required to determine the health of the biotic community, and the attainment of designated uses.

For each metric, at least two years of recent data are required to account for any temporal variability in the aquatic system. Historical data should also be analyzed if available to assess temporal variability. For a less-stringent SSC determination, the proposal must demonstrate that the proposed SSC is protective of the designated uses not only in the segment itself but also in any downstream waters. Therefore, sampling for biological metrics is required at multiple monitoring sites downstream of the SSC segment.

Once the complete dataset is obtained, modeling may be needed as part of the data analysis. Modeling techniques will need to be determined on a case-by-case basis. For instance, models such as BATHTUB are frequently be used by U.S. EPA and the department to validate appropriate lake/reservoir targets (United States Environmental Protection Agency, April 2000). Modeling is typically only available for chlorophyll *a* predictions, and would not be applied to other types of biological metrics.

7.4 APPLYING BIOLOGICAL METRICS FOR SSC DETERMINATION

As described in proposed ch. NR 119, the phosphorus response indicators and biocriteria are applied in the following ways to determine SSC eligibility:

Less stringent SSC: A waterbody or segment may be eligible for an SSC that is less stringent than the statewide phosphorus criterion in the following types of cases:

(1) The waterbody is exceeding its statewide phosphorus criterion but all of its phosphorus response indicators and biocriteria are attained. This can typically be demonstrated using only field data without modeling.

(2) If a waterbody is exceeding its statewide phosphorus criterion, and one or more of its phosphorus response indicators or biocriteria are not attained, a less-stringent SSC could be appropriate if a modeling analysis demonstrates that the phosphorus response indicators are expected to be attained if the waterbody's phosphorus concentration is sufficiently reduced to attain a proposed SSC that is less stringent than the statewide phosphorus criterion. (Example: Certain reservoirs with a statewide phosphorus criterion of 30-40 ug/L may fit in this category. For instance, a reservoir that is exceeding its statewide TP criterion of 40 ug/L with a current phosphorus level of 70 ug/L is also not attaining its chlorophyll *a* metric. In this case, modeling may demonstrate that an SSC of 50 ug/L TP should be sufficient to attain its chlorophyll *a* target; it does not need to attain 40 ug/L TP to reach its biological goals.)

(3) A less stringent SSC may be appropriate if a waterbody is not attaining the statewide phosphorus criterion because the natural background phosphorus concentration is higher than the statewide phosphorus criterion.

More stringent SSC: A more stringent SSC may be appropriate in the following types of cases:

(1) The waterbody attains its statewide phosphorus criterion but does not attain one or more of its phosphorus response indicators or biocriteria. Modeling may be required to determine at what level the SSC should be set to attain its biological metrics. However, a more stringent SSC is not appropriate if a biocriterion or phosphorus response indicator is not attained due to reasons other than phosphorus.

(2) A more stringent SSC may be appropriate even if a waterbody attains its statewide phosphorus criterion, phosphorus response indicators, and biocriteria in cases when it is demonstrated that a more stringent SSC than the statewide phosphorus criterion is necessary to maintain attainment of any of these indicators and the level necessary can be demonstrated through modeling.
(Example: Certain impounded flowing waters with a statewide phosphorus criterion of 100 ug/L may fit in this category. For instance, if an impounded flowing water currently has a phosphorus concentration of 50 ug/L TP and is attaining its biological metrics, a demonstration may show that an SSC of 70 ug/L TP is needed because its biological metrics will no longer be attained above that level.)

Proposed chapter NR 119 describes these processes in detail.

8. References

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